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Is it true that we all have a 'sleep animal'?
→p72

FROM THE EDITOR

We're terrible at spotting liars. Instinctively, we think we know when someone is lying to us, and sometimes we're right, but just as often we misread the cues.

Take, for instance, one of the most common 'facts' about lying: that you look up and to the left when you're being deceitful. False. Several studies have debunked this idea. We look around when we're recounting long, complicated stories because holding someone's gaze hogs the mental energy needed to communicate them clearly. In fact, one study by the University of Michigan analysed real court case data to discover that liars tended to look directly at the questioner for longer than truthful interviewees.

Science hasn't had much success either when it comes to spotting a fib. The polygraph (aka the lie detector test) is really just a measure of how stressed out you are. It's essentially combining data from your heart rate, sweat levels, respiration and blood pressure to determine the difference in your body between when you're speaking the truth, versus when you're lying. But studies have found that a skilled polygraph tester can only spot deception somewhere between 60 to 90 per cent of the time. That leaves a pretty sizeable margin for error. The American Polygraph Association itself says that the test is 86 per cent accurate. Or, to put it another way, for every 100 tests its members administer, 14 get it wrong. There have been other studies that attempt to use novel technology, like brain imaging tech to detect lies, but they ultimately fall foul of similar flaws.

So will we ever be able to definitively catch a liar? Well, it turns out we might. And you can find out exactly how on p56.

Daniel Bennett, Editor

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ON THE BBC THIS MONTH...

Just One Thing

Dr Michael Mosley's popular series returns to explore the big difference that small, simple changes can have on your life. This season kicks off with a subject that's close to all of our hearts: the health benefits hidden in a cup of tea.
BBC Radio 4
Also available on BBC Sounds

Uncanny

This supernatural show returns. If you missed the first season, like I did, check it out on BBC Sounds. The concept is brilliant: Danny Robins, the host, invites listeners to share their personal ghost stories – paranormal cold cases, if you like – and invites mystics and scientists to come up with explanations.
BBC Radio 4
Also available on BBC Sounds

Planet Earth 3

It's back! The first episode of this monumental series – years in the making – will hit your screens in November. We'll have a few special features based on it in the next couple of issues.
BBC One
Also available on BBC iPlayer

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VICTORIA GILL

BBC science reporter Victoria tells us what a recent encounter between French sailors and orcas can teach us about our relationship with animals. → p30

PROF JON BUTTERWORTH

Jon, a physicist, explains how the latest measurements of a subatomic particle could lead to the discovery of a fifth force of nature. → p34

DR JULIA SHAW

Psychologist Julia is often called upon to assess the veracity of statements given in court. Who better to tell us how to spot when someone is telling us fibs. → p56

MARCUS CHOWN

Neutrinos fly through planets like ghosts through walls. Radio astronomer and author Marcus reveals how they'll help us explore the Universe. → p64

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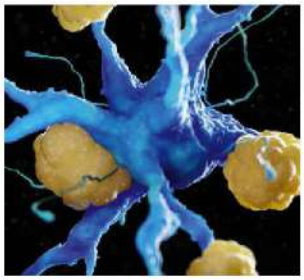

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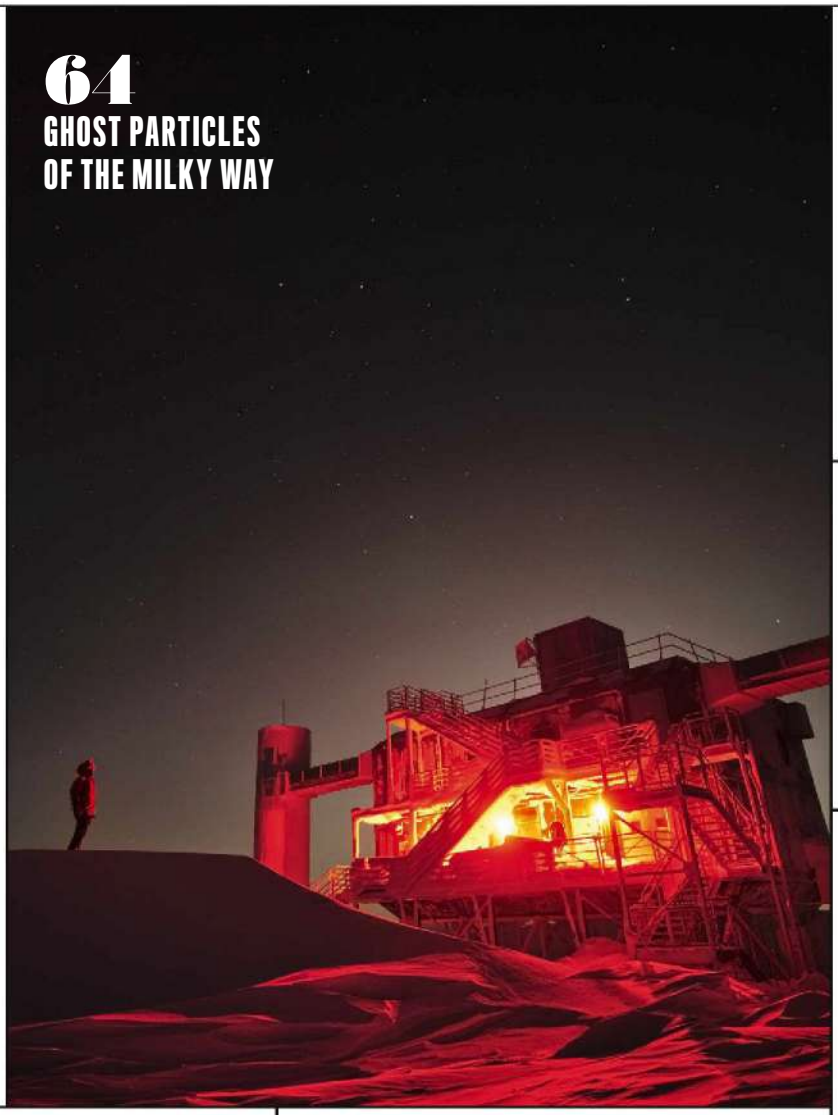

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"ORCAS ARE COMPLEX, INTELLIGENT ANIMALS WITH CULTURE AND DEEP FAMILIAL BONDS"

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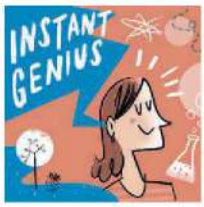

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EYE OPENER

Red lightning

LAKE PUMA YUMCO, TIBET

This may look like the trailing tentacles of a swarm of jellyfish, but it's actually a rare atmospheric phenomenon known as a sprite. (It's also the winning image of the 'skyscapes' category in the 2023 Astronomy Photographer of the Year competition.)

"This electrical discharge occurs much higher in the atmosphere than normal lightning," says Royal Observatory astronomer Dr Ed Bloomer. "While the gradient of colours is beautiful by itself, the image also reveals the delicate structure of the plasma."

Also known as 'red lightning', atmospheric sprites are caused by intense lightning discharges, which create powerful, upward-propagating electrical fields that ionise the upper atmosphere. They're associated with powerful thunderstorms, but only exist for a fraction of a second – making them harder to study than lightning that strikes downward. They're also much bigger: up to 48km (30 miles) in diameter.

ANGEL AN/APY

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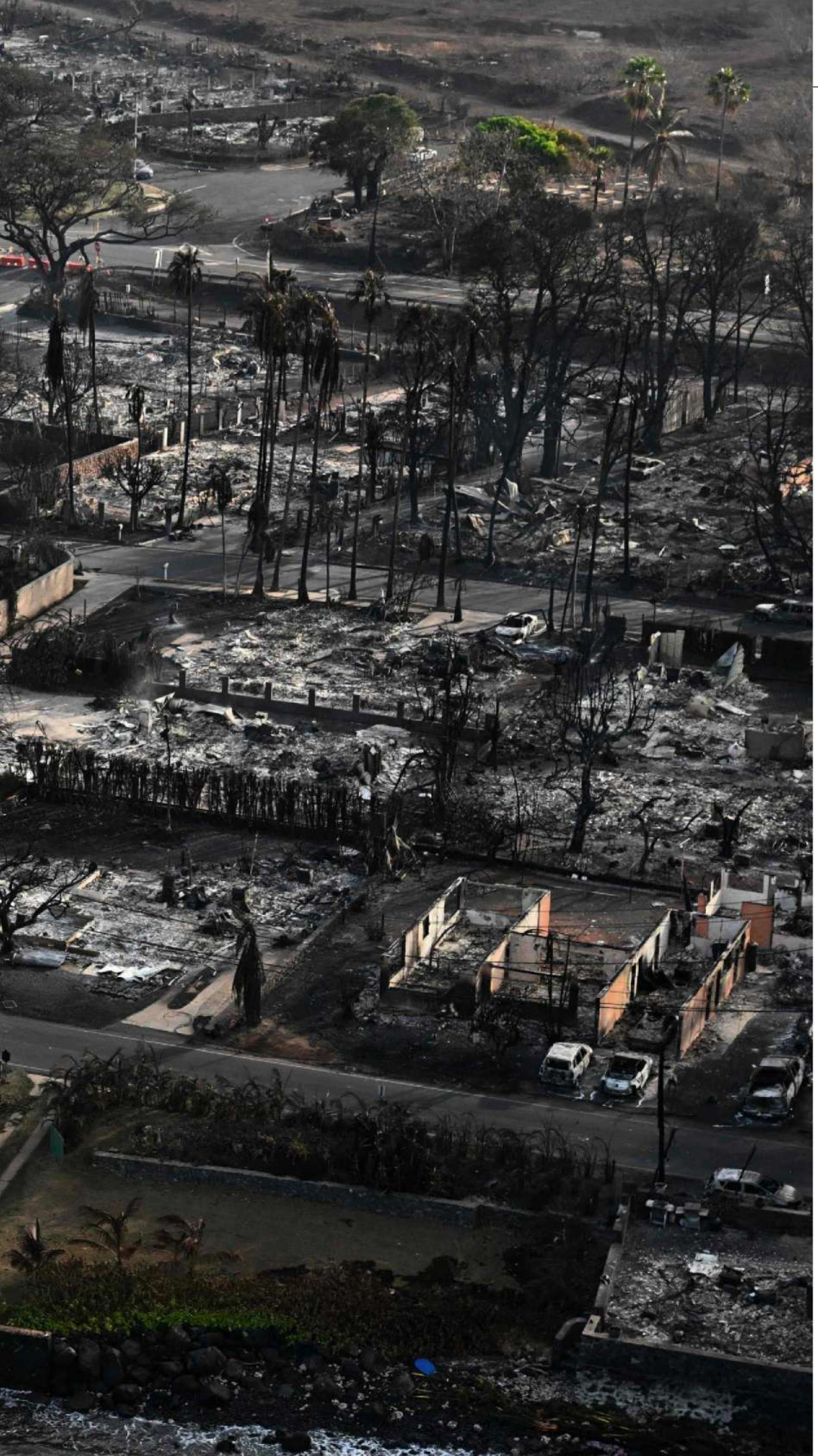

EYE OPENER

Narrow escape

HAWAII, USA

On 8 August, wildfires blazed across the Hawaiian island of Maui. They were intensified by fast, dry winds that whipped up the fire's hot embers and dropped them on drought-shrivelled vegetation and the roofs of people's houses.

The reason this house managed to escape largely unscathed is thought to be due to renovations carried out by its owners. They replaced the asphalt roof with a metal one, surrounded the house with stones and removed the overgrown foliage, although none of these changes were eplicitly intended as a means to fire-proof the property.

"The image contains signs of extreme heat and vast spread to the very last bit of land, even burning the boats in the harbour," said Guillermo Rein, Professor of Fire Science in Imperial College London's engineering department.

"Despite [wildfires] being an old concern, climate change is creating conditions that could make them more devastating by drying the vegetation. That puts even more lives and homes at risk."

The Hawaiian wildfires destroyed most of the historic town of Lahaina and killed 97 people.

GETTY IMAGES

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EYE OPENER

Persian gold

ZAGROS MOUNTAINS, IRAN

Bad news for arachnophobes: in a recent issue of the journal *ZooKeys*, researchers announced the discovery of this new – and rather alarming-looking – species of spider.

Spotted in northwestern Iran, the new species has been given the scientific name *Chaetopelma persianum* and is a tarantula of a genus first described in 1871. The six species in this genus are found in an arc stretching from southeastern Europe, around the Middle East and down into Africa, through the likes of Greece, Turkey, Cyprus, Syria, Egypt, Sudan and Cameroon.

These tarantulas – members of the much-larger *Theraphosidae* family – occupy burrows or silk-lined chambers constructed under large stones or boulders.

Found in the northern Zagros Mountains, this latest addition to the family is the easternmost known example of the genus, and one of only three tarantulas found in Iran.

With an estimated span of around 9cm (3.5in) the palm-sized spider – identified from a single female specimen – is covered in woolly hairs that have a blonde, almost-golden hue. Hence it's newly minted common name: the Persian gold tarantula.

KARI KAUNISTO/COVER IMAGES

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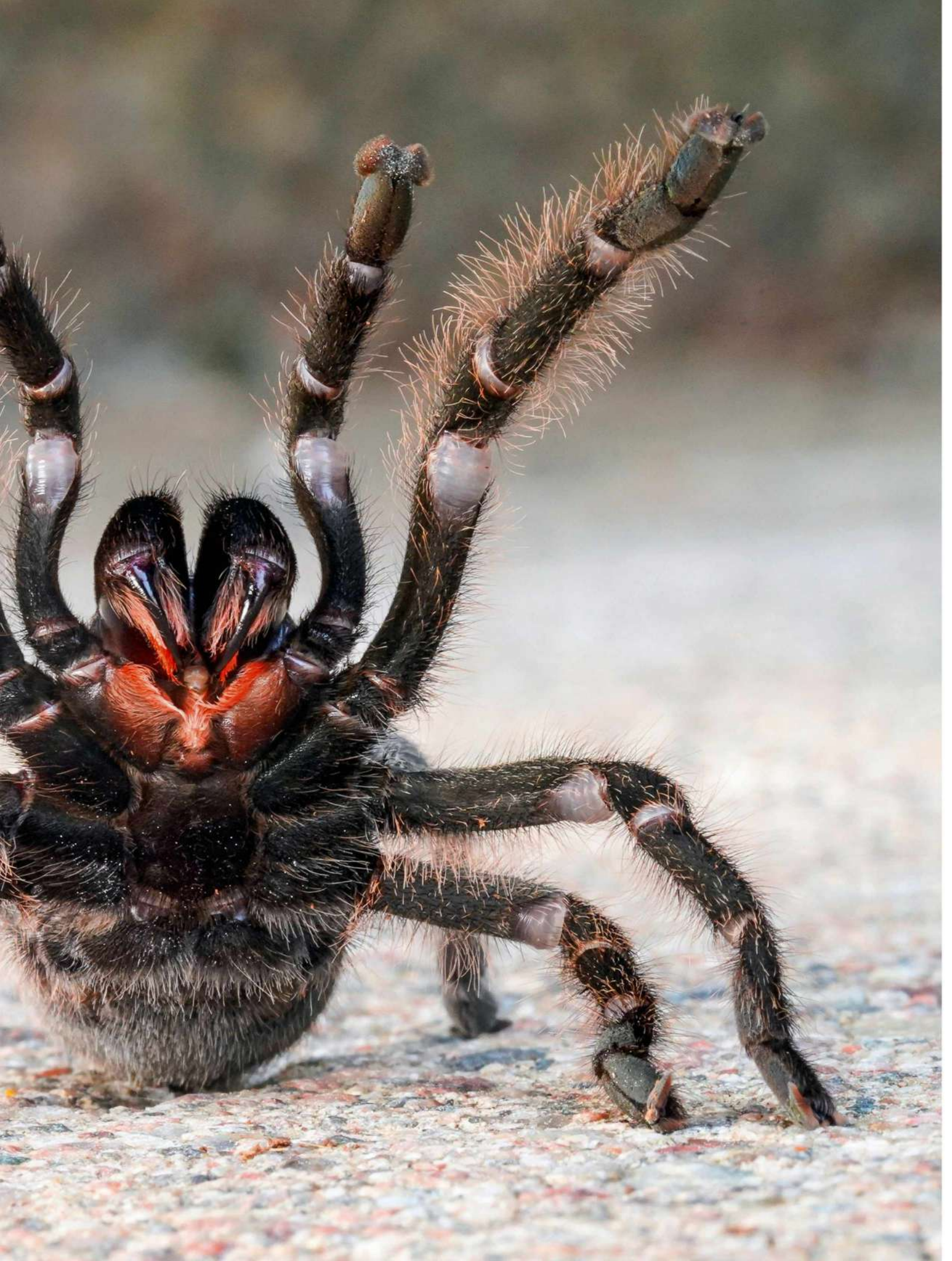

FEEDBACK

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND OUR MAGAZINE

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LETTER OF THE MONTH

A cure for hiccups? That's nuts

I'm writing not with a question, but with a cure for hiccups (Summer, p80). My mother read about it somewhere years ago and it works for our family 99 per cent of the time. It's a spoonful of peanut butter. My daughter, now 24, seems to be prone to hiccups and it has worked for her since she was about five. Other friends and relatives also find it to be successful.

Ramona Cronin, via email

WRITE IN AND WIN!

The writer of next issue's *Letter of the Month* wins ***a trio of hardback science books***. Put pen to paper (or fingertips to keyboard) and you could get your hands on *Chip War* by Chris Miller; *Future Stories* by David Christian; and *The End of Astronauts* by Donald Goldsmith and Martin Rees.

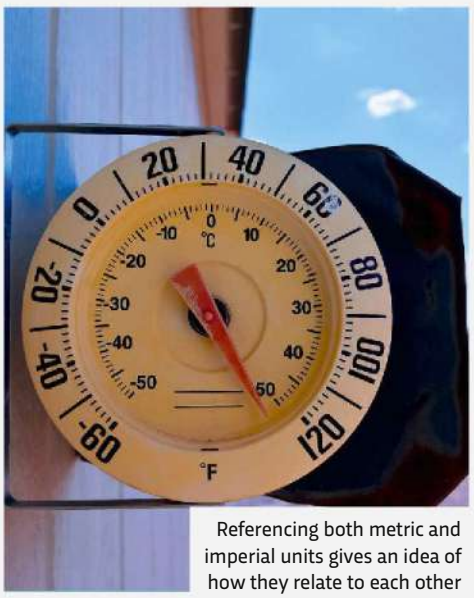
The logical alternative

Reflecting on deep-sea mining debates (August, p24), it would seem logical for the resources and funding being ploughed into the endeavour to instead be invested in recycling rare metals from electronic waste. Given the vast quantities of electronic waste produced globally, this would provide a sustainable, closed-loop supply of these metals, tackle the impacts of electronic waste pollution and prevent damage to deep-sea ecosystems. It would use metals we've already extracted, rather than risking long-term damage from deep-sea mining, which would only end up generating further electronic waste pollution if recycling strategies aren't developed!

Morag Hewett, via email

Assumed knowledge

Reading the Q&A about fusion power (September, p77), I was struck by the fact that you gave temperatures in both Celsius and Fahrenheit. I'm pretty sure that all of your readers – even Americans – are familiar with Celsius and metric by now, or is there some



Referencing both metric and imperial units gives an idea of how they relate to each other

"AFTER TWO WEEKS OF INTENSIVE EXERCISE, ALTHOUGH I DIDN'T LOSE ANY WEIGHT, I'M UNDENIABLY FITTER AND, ACCORDING TO MY WIFE, MY MOOBS HAVE SHRUNK"

PROF GILES YEO, p28

Salvaging and recycling rare metals from electronic waste may be a less harmful alternative to deep-sea mining

GETTY IMAGES X3

benighted corner of the world where these systems are unknown?

Alan Blackwood via email

The case for space exploration

With regards to Paul Spraggins's letter (September, p12) querying the value of space exploration, might I point out that the study of Venus and its hot, dense atmosphere has shed a great deal of light on the issue of global warming.

Rudyard Kipling once wrote: "And what should they know of England, who only England know?" By the same token, "And what should they know of Earth, who only Earth know?"

The late, award-winning science-fiction author Robert A Heinlein once expressed a similar sentiment: "The Earth is just too small and fragile a basket for the human race to keep all its eggs in."

Thinking along the same lines, another sci-fi writer, Larry Niven, observed that: "The dinosaurs became extinct because they didn't have a space program. And if we become extinct because we don't have a space program, it'll serve us right!"

Peter Davy, Bournemouth

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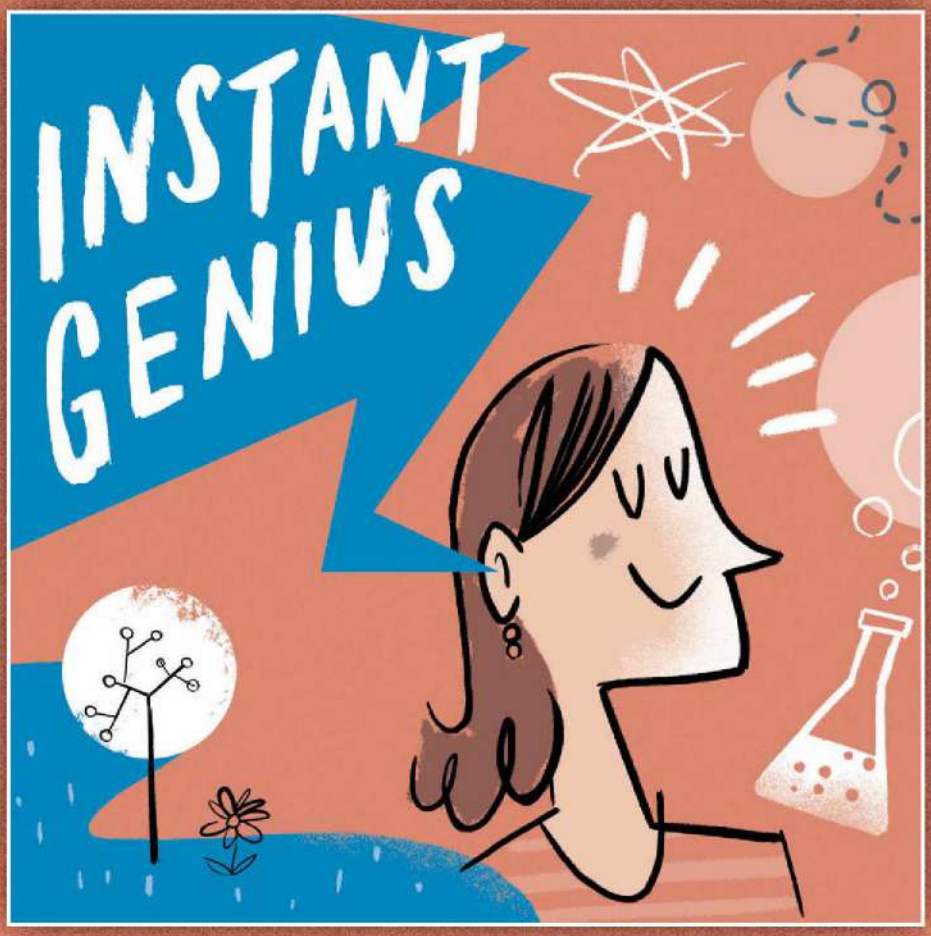

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with
Dr Tanja Radu

NUCLEAR WASTE
with
Dr Lewis Blackburn

THE UNIVERSE
with
Dr Neil deGrasse Tyson

OCEAN CURRENTS
with
Dr Helen Czerski

DISCOVERIES

"We were stunned to see that nuclear weapons fallout still impacts the ecosystem to such a great extent"
Dr Georg Steinhauser **p21**

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A new technique for sneaking drugs into the brain offers hope for treating Alzheimer's **p16**

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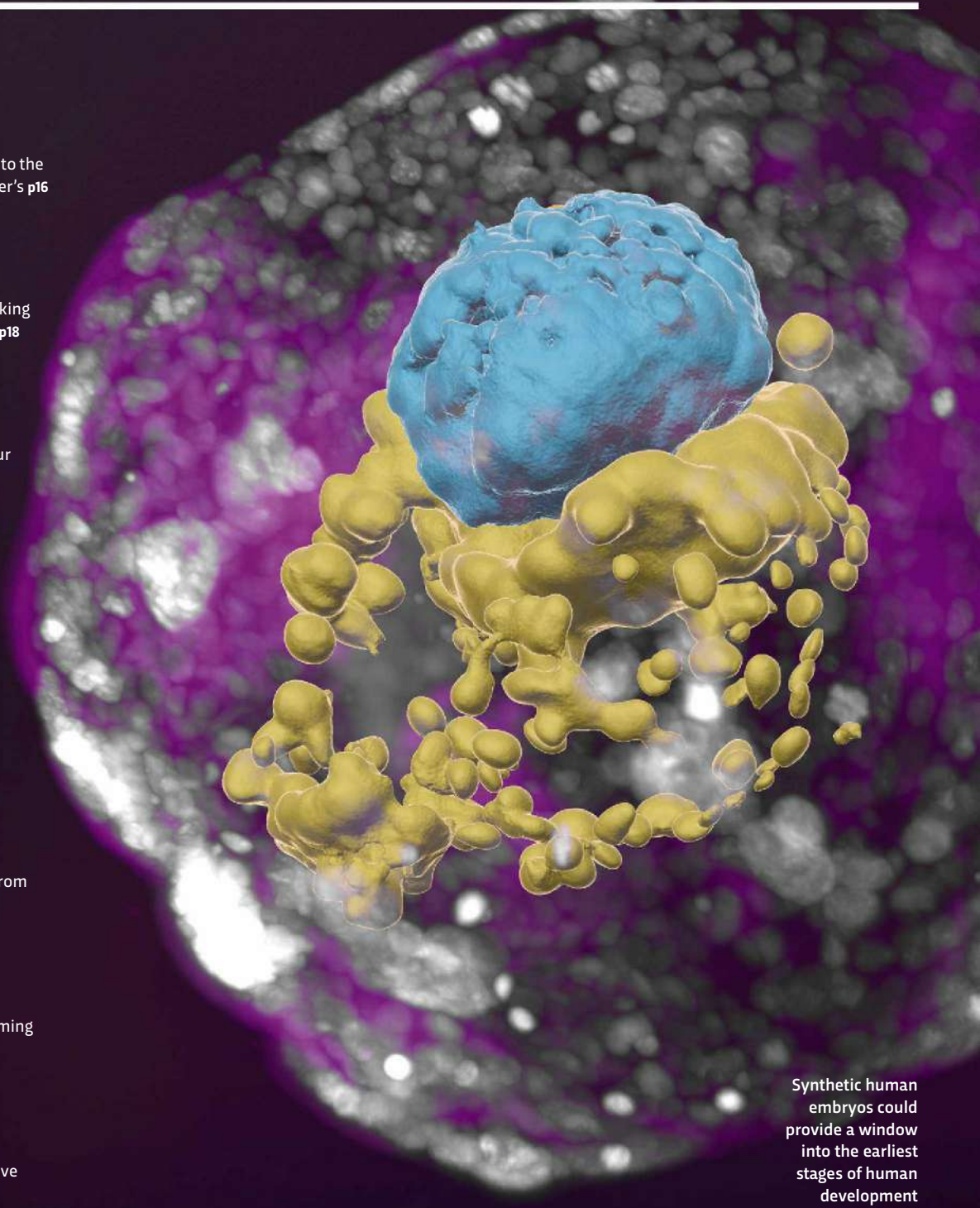

PROFESSOR JACOB HANNA

Synthetic human embryos could provide a window into the earliest stages of human development

MEDICINE

NEW ULTRASOUND TECHNIQUE COULD ENABLE BRAIN TREATMENTS... AND, ONE DAY, DELAY AGEING

A new drug delivery system brings scientists a step closer to curing brain disorders such as Alzheimer's. But the scientists behind it are aiming even higher

A breakthrough medical technique has unlocked "unlimited" possibilities for more effective treatment of Alzheimer's disease, tumours and other brain diseases.

The scientists behind the discovery, based at Imperial College London, believe that the new method, which involves "bubbling drugs into the brain", could also prevent diseases from developing. It may also have the potential to delay brain ageing and slow memory loss.

Alzheimer's is the most common form of dementia and, worldwide, there are some 55 million people living with it. There is currently no cure for the disease, nor most other brain diseases.

This is partly because the blood-brain barrier (BBB) in our brains inhibits the delivery of most drugs. The BBB is there to protect the neurons in the brain and it does so by acting like a border control post – stopping harmful toxins and pathogens from entering.

The trouble is the BBB also prevents powerful medicines from reaching the places where they're needed, often because those molecules are too big to pass through. Even smaller molecules have a hard time crossing; more than 98 per cent of small-molecule drugs are excluded by the BBB.

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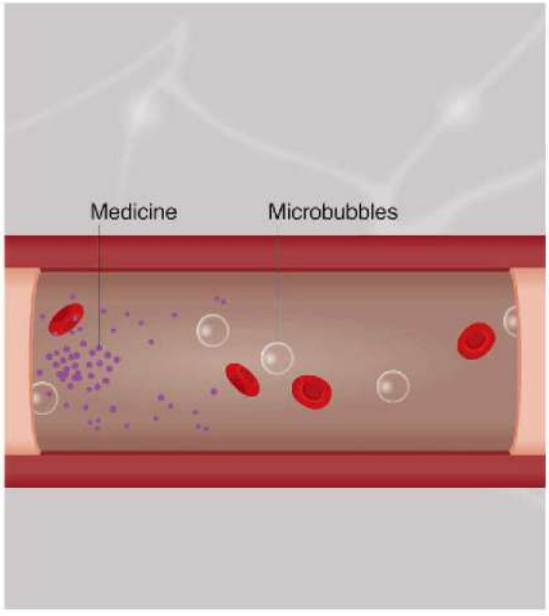
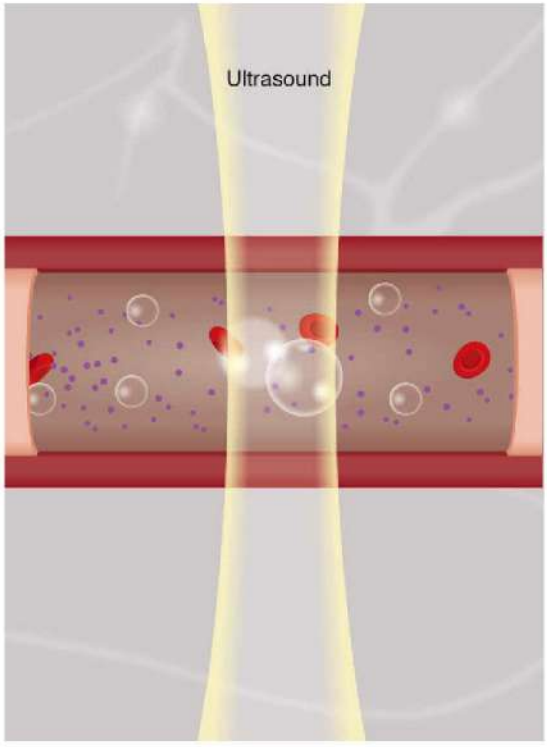
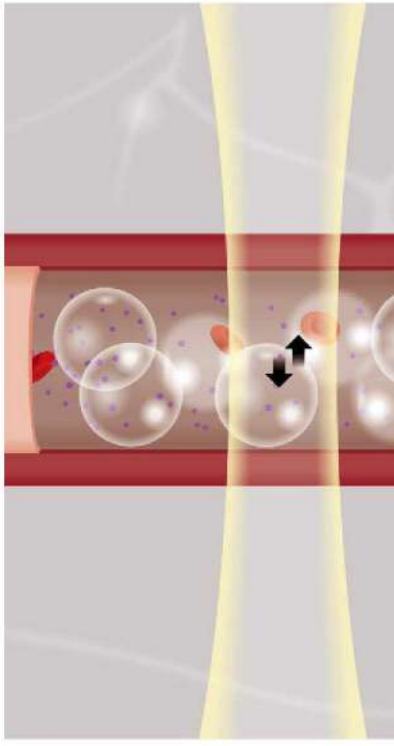






How to bubble drugs into the brain

1. Scientists inject microbubbles containing non-harmful gases into the bloodstream. The patient is also given their medicine, which may be in the form of an injection or pill.

2. At the same time, scientists administer low-frequency ultrasound to the affected area of the brain. When the bubbles reach this area, the ultrasound causes them to expand.

3. The bubbles push the walls of the blood vessel outwards, creating gaps in the blood-brain-barrier.

Dr Sophie Morse is a Research Fellow in Bioengineering at Imperial and the lead author of the paper describing the new technique published in *Nature Scientific Reports*. The paper reveals how Morse and her colleagues "broke into the brain" by combining ultrasound with microbubbles to temporarily open the BBB, allowing a range of drugs through.

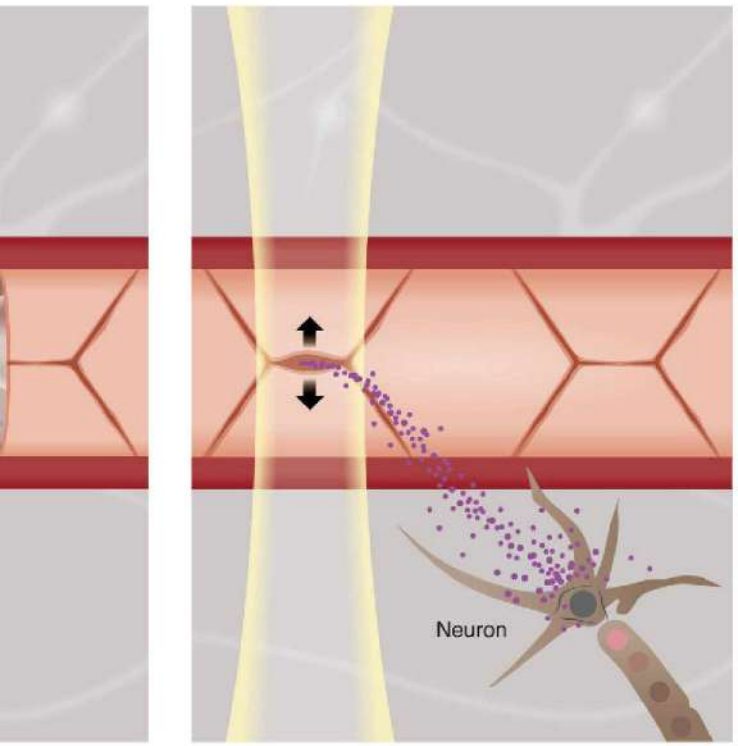
"[The technique] opens up this massive door to basically unlimited options," Morse told *BBC Science Focus* during the British Science Festival in September.

By opening the BBB this way, the team was able to remove 50 per cent of Alzheimer's plaques in just two months. If left untreated, those plaques would eventually envelop and then kill neurons, causing memory loss.

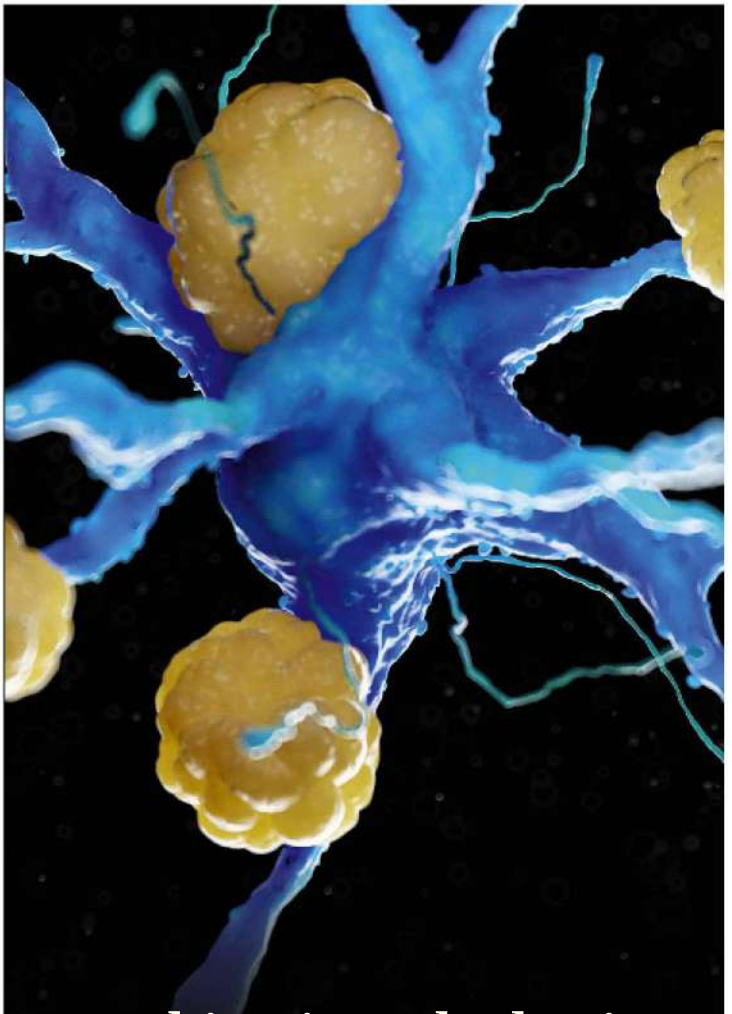
It's the first time that short-wave ultrasound has been used to deliver such a wide range of drugs into living organisms (in this case, mice).

Clinical trials on humans started in the US three years ago and are now beginning in the UK. Morse hopes that this method could be used to treat patients within the next decade.

"I'd hope that by the time we get old, we can get older in a nicer way because of this," Morse said.



4. The gaps remain open temporarily to limit the passage of bad molecules (closing in 10 to 20 minutes in the study). The medicine molecules can now reach the diseased neuron.

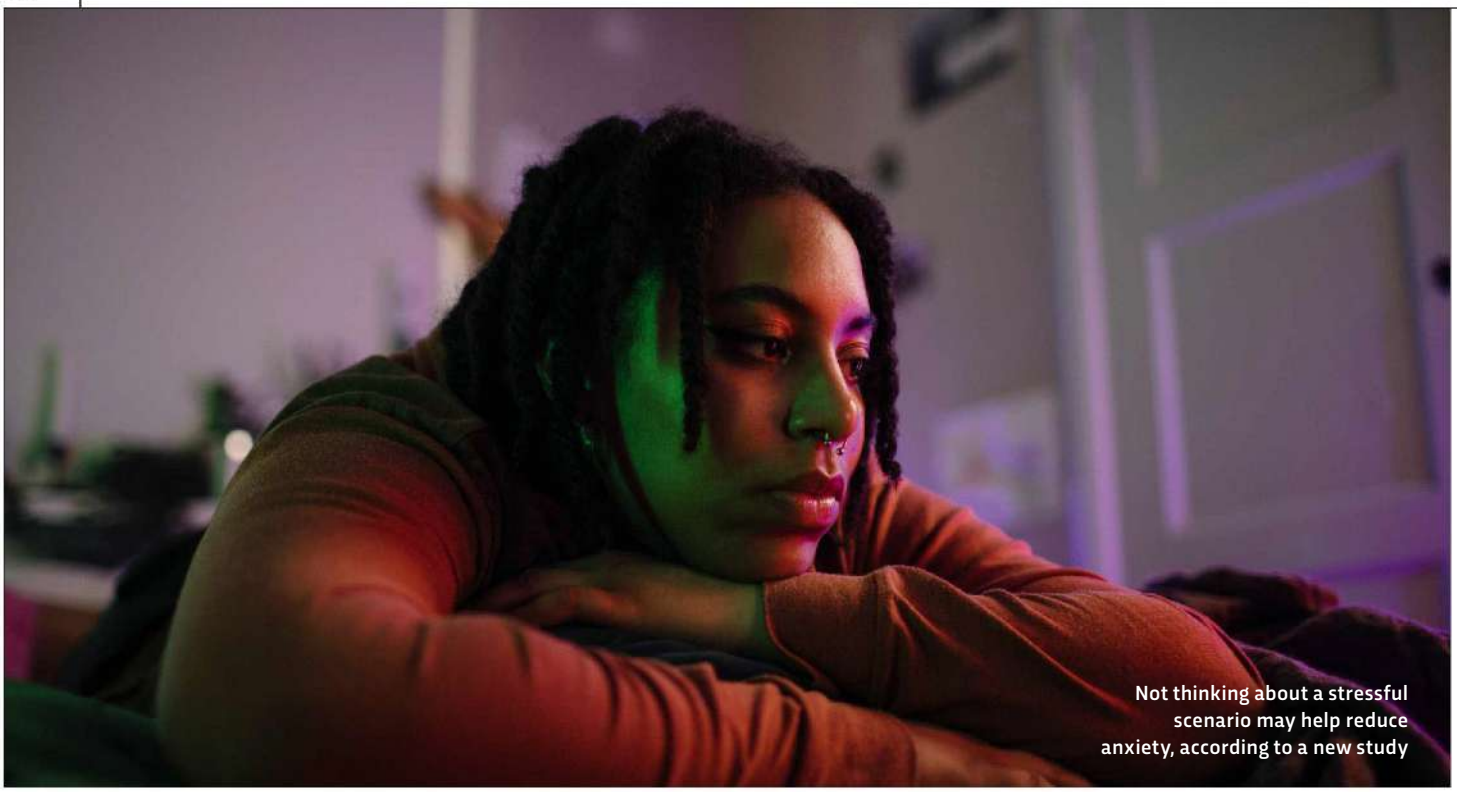


Breaking into the brain to delay ageing

In the future, the new method of opening the blood-brain barrier could be used to help delay the effects of ageing on the brain. "It sounds very sci-fi, but the theory is there and it should work," Dr Sophie Morse told *BBC Science Focus*.

Morse suggests that openings in the blood-brain barrier created using this method could enable stimulation of the brain's immune cells. She thinks that this would alert tired immune cells to unwanted substances. These immune cells might then be prompted to shake off plaque as it forms, engulfing that deleterious material and breaking it down. This could prevent Alzheimer's, and even tumours, from developing.

"The very futuristic vision," Morse says, "is that you'd have [brain treatment] clinics, similar to those you'd go to for a blood test, where you could sit in a chair, have a hair-salon helmet put over your head, have a quick zap, and then continue with your shopping."



Not thinking about a stressful scenario may help reduce anxiety, according to a new study

PSYCHOLOGY

'BLOCKING' NEGATIVE THOUGHTS MAY HELP MENTAL HEALTH, SAYS CONTENTIOUS STUDY

A new technique could provide relief for people with anxiety, but has been met with scepticism by some scientists

Have you ever had a problem and been told to just "try not to think about it"? As frustrating as it might be to hear, new research suggests that it might be helpful advice for combatting negative thoughts.

In a University of Cambridge experiment, researchers trained volunteers to suppress thoughts about things that worried them. The results, published in the journal *Science Advances*, show that participants' negative concerns became less intrusive and that their mental health improved.

The researchers say that the training activated a brain mechanism known as inhibitory control, which gives us the ability to override our reflexive reactions, including retrieving negative thoughts from our memory.

To test this, they asked 120 volunteers to think of several scenarios that could occur within the next two years. These included negative fears and concerns, positive hopes and dreams, and neutral or routine events.

The researchers then showed some volunteers a word to remind them of one of their negative scenarios, and gave others a neutral cue. Participants were then asked to stare at the cue word for 20 minutes, during which time they were told to try not to imagine their given scenario.

> "Scenarios that participants tried to suppress became less vivid"

In the next phase, the researchers gave some volunteers a positive cue and others a neutral cue again. This time, they had to imagine the scenario in as much detail as possible. (For ethical reasons, the scientists didn't ask volunteers actively to imagine negative events.)

The volunteers then rated the vividness of the imagined events, their levels of anxiety and the frequency of intrusive thoughts before and after the trials. They also completed mental health questionnaires.

The researchers found that the scenarios participants tried to suppress became less vivid and less anxiety-inducing. The volunteers also reported improved mental health after the trial and three months later.

Luis Valero Aguayo, Professor of Psychology at the University of Malagá, Spain, who wasn't involved in the experiment, said that the study was "well-planned and well-conducted". However, Aguayo pointed out that there's no way of controlling or knowing what the volunteers were imagining.

"You can't 'keep your mind blank', as the authors claim," he added. "Simply stating to a person 'don't imagine the hospital' … already gives a stimulus to automatically think of a hospital, even if they don't want to."

GETTY IMAGES, NICK KAAZ/NORTHWESTERN UNIVERSITY

SPACE

BLACK HOLES ARE TEARING THROUGH SPACE-TIME MUCH QUICKER THAN SCIENTISTS THOUGHT

3D simulations of black holes demonstrate their hungry ways and could begin to explain dramatic episodes in the life of a quasar

As if black holes weren't terrifying enough already, recent research shows that they 'eat' at much faster rates than previously expected.

Astrophysicists at Northwestern University, in the US, used supercomputer simulations to track the consumption rates of black holes more accurately.

These high-resolution 3D simulations show spinning black holes twisting up the surrounding space-time, ripping apart the whirlpool of gas that both encircles and feeds them. This action results in the gas whirlpool being torn into separate inner and outer discs.

These whirlpools are known as accretion discs. Such a disc comprises gas, plasma, dust and other particles orbiting the gravitational field of an object – in this case, the black hole.

First the black hole devours the inner disc, then debris from the outer disc spills inwards, refilling the gap left behind. Then that's eaten and so on.

The 3D simulations revealed that one cycle of this process takes just a few months – a far shorter period than the hundreds of years previously suggested by scientists.

This new research could help to explain the erratic behaviour of bright objects in the night sky. These include quasars, bright galactic cores falling into black holes that abruptly flare up and then vanish.

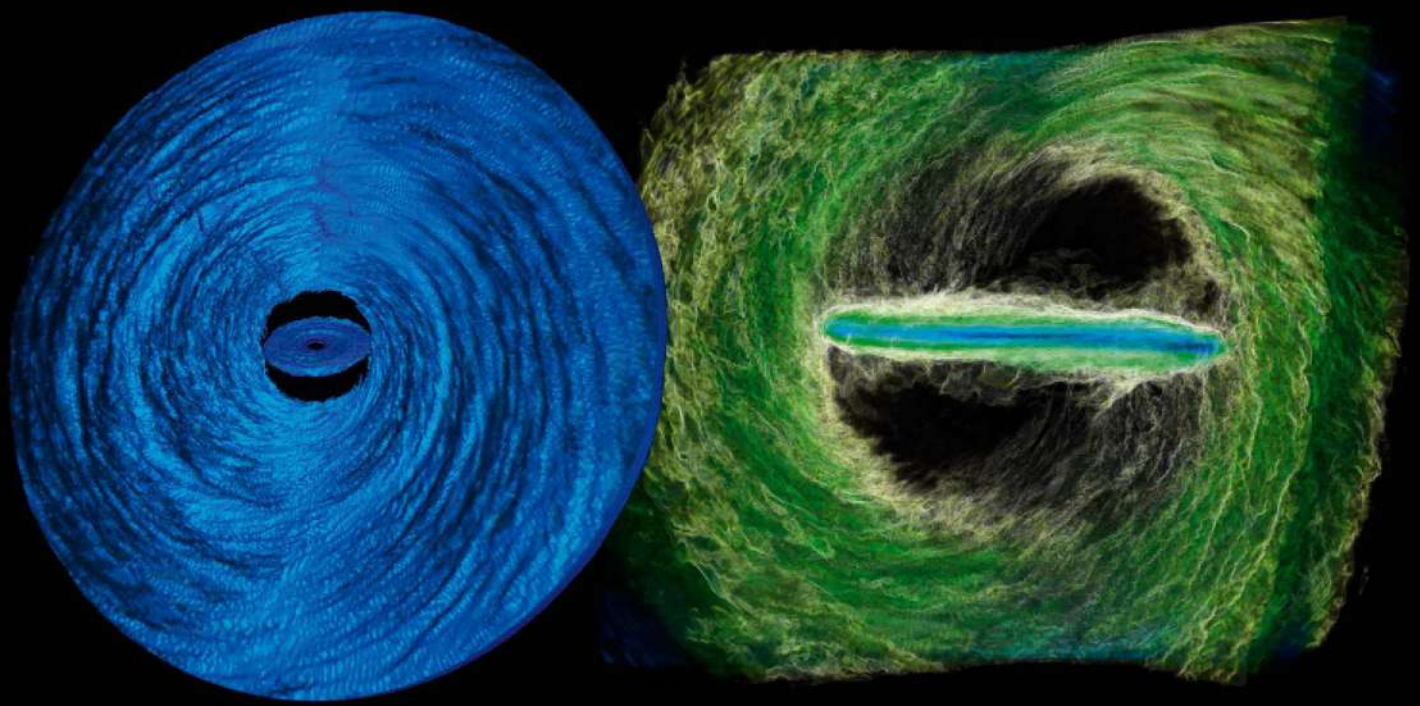
"Classical accretion disc theory predicts that the disc evolves slowly," said Nick Kaaz, who led the study. "But some quasars, which result from black holes eating gas from their accretion discs, appear to drastically change over time scales of months to years.

"Classical accretion disc theory can't explain this drastic variation," he added.

Previous studies suggested that accretion discs, though dramatic in nature, are relatively orderly. That research proposed that gas and particles swirl around a black hole, gradually feeding it over the course of hundreds of thousands of years.

The new simulations, though, show that the tearing region – where the inner and outer sub-discs disconnect – is the location of a black hole feeding frenzy. As friction tries to keep the disc together, the twisting of space-time by the black hole acts to pull it apart.

These simulations could help answer ongoing questions about the nature of black holes, including how they form, how long they last and what astronomers are actually seeing when they observe them through telescopes.



A new simulation shows how a black hole rips its surrounding accretion disc in two

REPRODUCTION

SCIENTISTS GROW SYNTHETIC HUMAN EMBRYOS FOR 14 DAYS WITHOUT EGGS, SPERM OR A WOMB

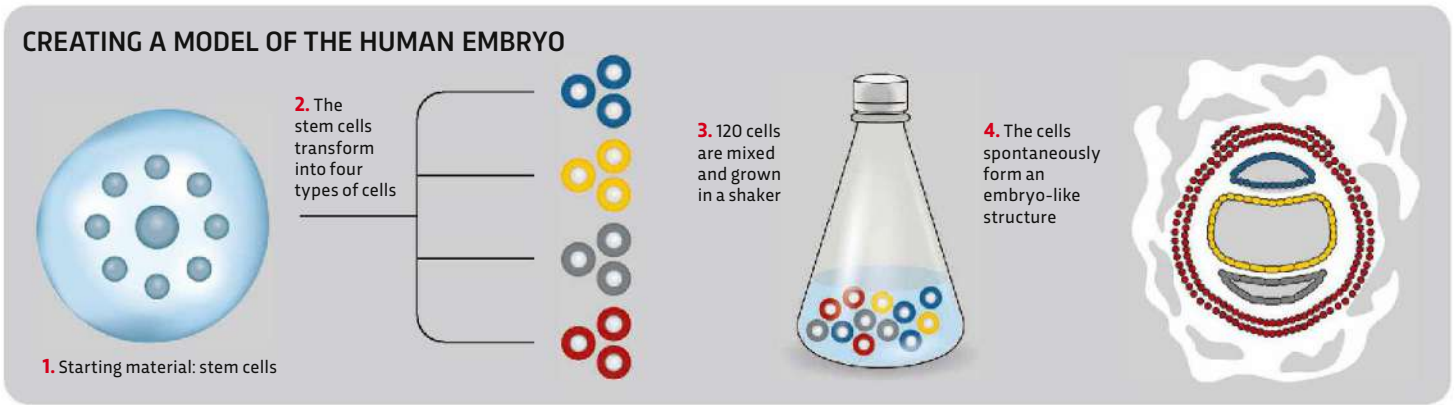
The milestone research will help to unlock fresh insights into the first month of human development, but also raises important ethical questions

In a groundbreaking development, scientists have grown synthetic human embryos for 14 days, without eggs, sperm or a womb.

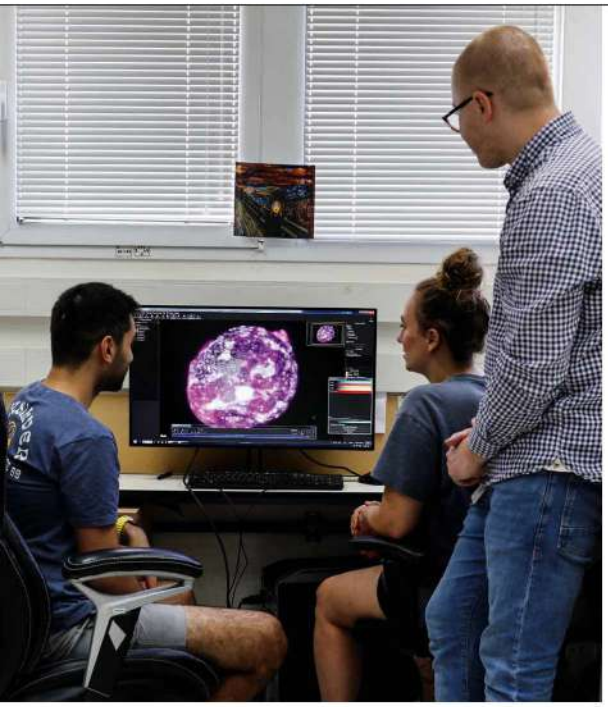
A research team from the Weizmann Institute of Science in Israel generated the synthetic embryos using pluripotent stem cells, which have the potential to develop into many different cell types. The resulting embryos, described in a new study published in *Nature*, mimic the 3D structure and key characteristics of a human embryo.

Previous synthetic embryos have been missing certain crucial hallmarks, including the cells that form the placenta and yolk sac. But the synthetic embryos in this new study include a placenta and a yolk sac to support the embryo's growth, marking a significant first.

The legal limit on natural embryo experimentation is 14 days, so scientists currently know very little about the early development of human embryos. Yet this


CREATING A MODEL OF THE HUMAN EMBRYO
1. Starting material: stem cells
2. The stem cells transform into four types of cells
3. 120 cells are mixed and grown in a shaker
4. The cells spontaneously form an embryo-like structure

REUTERS X2, GETTY IMAGES, WEIZMANN INSTITUTE OF SCIENCE/NATURE/ACUTE GRAPHICS



Experts investigate the synthetic embryos developed in Israel's Weizmann Institute of Science

is the crucial stage of development during which a group of cells begins to form the structure that, within four weeks, will contain all the organs.

"The drama is in the first month," explained Prof Jacob Hanna, who led the research. "The remaining eight months of pregnancy are mainly lots of growth, but that first month is still largely a black box."

"Our stem-cell-derived human embryo model offers an ethical and accessible way of peering into [the black] box," Hanna added. "It closely mimics the development of a real human embryo, particularly the emergence of its exquisitely fine architecture."

The scientists hope that the findings will facilitate deeper investigation into infertility and the growth of tissues for transplants.

The researchers are keen to emphasise that, despite their similarities, the synthetic embryos are not real embryos. It's unclear how long the synthetic embryos would survive if allowed to develop beyond 14 days.

But while it's currently illegal to implant synthetic embryos into a human womb, there's no legal framework addressing the ethical issues of synthetic embryos.

Darius Widera, Professor of Stem Cell Biology and Regenerative Medicine, University of Reading (who wasn't involved in the research), said that the research "show[s] that models are getting more sophisticated and closer to ... normal development, highlighting that a robust regulatory framework is needed more than ever."

NATURE

THERE ARE RADIOACTIVE BOARS LURKING IN GERMAN FORESTS

If you go down to the woods today, you're sure of a big surprise

Populations of wild boars are expanding across Europe, but scientists have warned that they shouldn't be eaten because they contain unsafe levels of the radioactive metal caesium.

High levels of radioactivity have been recorded in wild boars for decades. It was long thought that the 1986 Chernobyl disaster in Ukraine caused the shaggy, tusked creatures roaming the forests of Germany and Austria to become radioactive.

But researchers from the Vienna University of Technology in Austria have now shown that nuclear weapons testing from the mid 20th century is largely responsible.

The study, published in the journal *Environmental Science & Technology*, pinpoints the cause: atmospheric nuclear weapons tests conducted across the world by various nations in the 1950s and 1960s.

"We were stunned to see that nuclear weapons fallout still impacts the ecosystem to such a great extent," the paper's corresponding authors Dr Georg Steinhauser and Dr Bin Feng told *BBC Science Focus*.

When nuclear weapons explode or nuclear energy is produced, radioactive caesium is created, which can be harmful to humans.

Both the Chernobyl disaster and earlier weapons tests contaminated the boars' food, including truffles. In the decades following Chernobyl, the radioactive isotope caesium-137 was detected in game animals, but levels fell over the following years. However, caesium-135 – an isotope with a much longer half-life – was found in the boars.

European wild boars are contaminated with fallout from nuclear weapons tests

The study's authors used a gamma-ray detector to measure caesium levels in boar meat from southern Germany. They also compared levels of caesium-135 and caesium-137 using a mass spectrometer to determine their sources.

The high ratio of caesium-135 to caesium-137 detected indicates that the contamination resulted primarily from weapons testing rather than nuclear reactors. Across the samples obtained, between 10 and 68 per cent of the contamination came from tests of nuclear weapons. And 88 per cent of the meat samples analysed contained radioactivity exceeding safe levels in food.

"It's a cautionary tale that the long-forgotten atmospheric nuclear weapons tests and their fallout still cast a shadow on the environment," Steinhauser and Feng told *BBC Science Focus*. "Just because they took place 60 years ago doesn't mean that they no longer impact the ecosystem."

ARCHAEOLOGY

SCIENTISTS RECREATE EGYPTIAN MUMMY'S 3,500-YEAR-OLD 'SCENT OF ETERNITY'

Hints of vanilla and Tarmac characterise the embalming fluid use to mummify an ancient noblewoman

When British archaeologist Howard Carter excavated Tutankhamun's burial chamber over 100 years ago, he also brought out two jars from another tomb that contained residue of the balm used for mummification. The balm's distinctive smell, dubbed 'the scent of eternity', is now something you can sample for yourself, thanks to scientists at the Max Planck Institute of Geoanthropology in Germany.

The scientists worked with French perfumers to recreate the balm's smell. This is an olfactory replica of the substance used to embalm the organs of an important Egyptian woman who lived over 3,500 years ago in the Valley of the Kings.

A study published in the journal *Scientific Reports* describes the ingredients used to create the balm for a woman, named Senetnay, who died around 1450 BCE. The scientists analysed the balms found in the jars excavated from the tomb using mass spectrometry. They discovered that the balms contain a blend of beeswax, plant oils, resins, fats and bitumen (the naturally occurring material used in road construction that gives Tarmac its unmistakable smell).

Some of the compounds detected in the balm, including vanillic acid and coumarin, suggest the balm may have had a vanilla-like odour. The scent will be on display as part of an immersive exhibition at Moesgaard Museum in Denmark.

One of the jars that contained the embalmed organs of Senetnay

HEALTH

TAKING CARE OF YOUR TEETH COULD PROTECT YOU AGAINST CANCER

You don't need dazzling pearly whites, but scientists say a good set of gnashers and regular trips to the dentist are important

It's been a long day, and you've just got cosy in bed when you remember you haven't brushed your teeth. We've all been there. But new research shows that taking good care of your gnashers gives you a much higher chance of surviving some forms of cancer.

Researchers at the University of North Carolina, in the US, studied the health data of 2,500 head and neck cancer patients from across the world.

They found that people who visited the dentist regularly and had more of their natural teeth (as opposed to no teeth or fake teeth) before their cancer diagnosis were more likely to survive.

The study, published in the *Journal of the National Cancer Institute* counts at least six visits to the dentist within a decade as frequent.

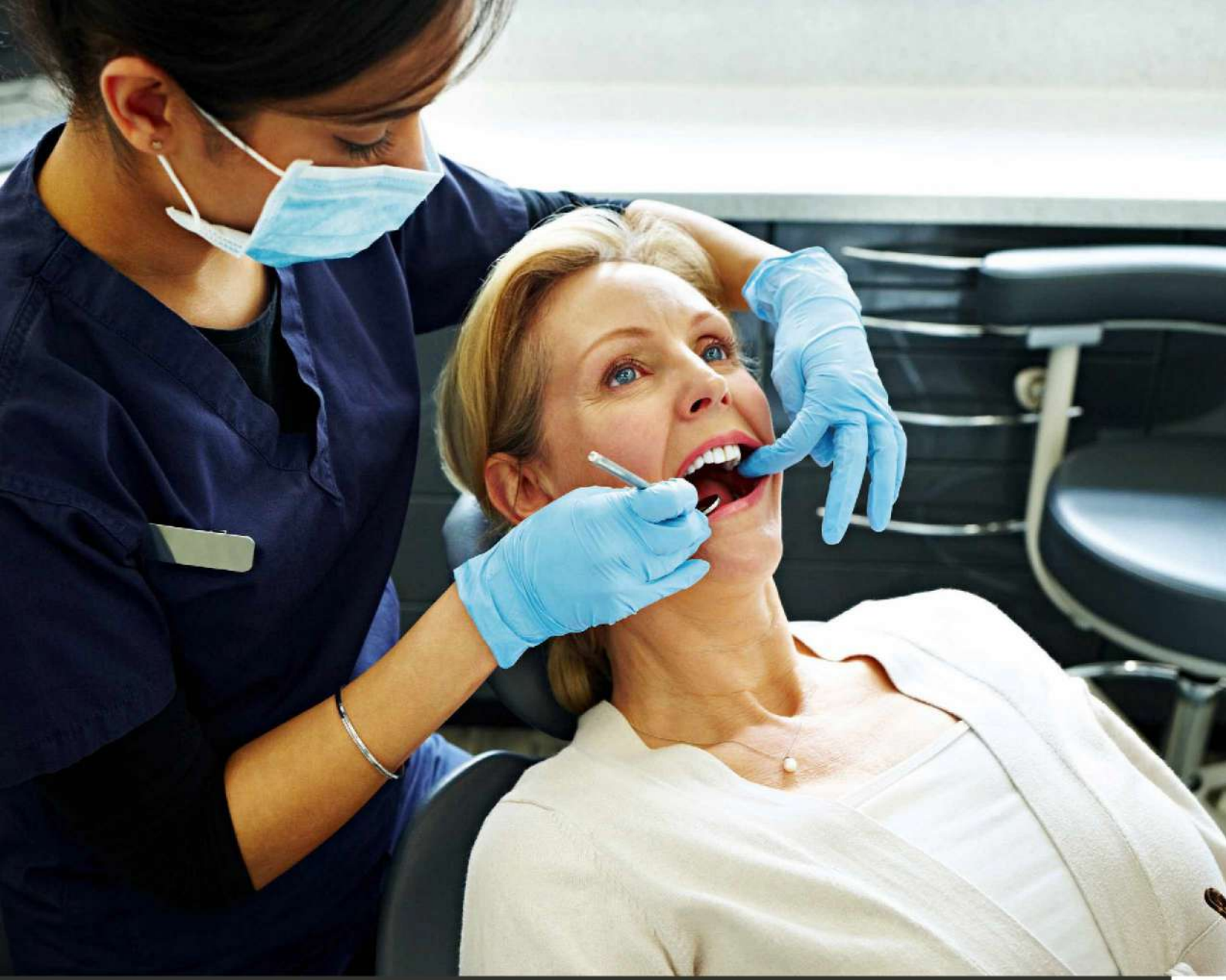
People who visited the dentist frequently had a 74-per-cent survival rate over a five-year period, compared to a 54-per-cent survival rate in those who didn't visit the dentist at all.

Going to the dentist more often increases your chances of being diagnosed with cancer early, catching the disease at a less-deadly stage and providing crucial time for treatment.

Patients with no remaining natural teeth were 15-per-cent less likely to survive over a five-year period than people with more than 20 natural teeth. Most adults have 32 teeth – or 28 if your wisdom teeth have been removed.

Using data from the International Head and Neck Cancer Epidemiology consortium, the researchers also analysed data concerning other aspects of cancer patients' oral health. As well as patients' dentist visits and natural teeth counts, they looked at their gum

GETTY IMAGES, MUSEUM AUGUST KESTNER/CHRISTIAN TEPPER



bleeding, teeth brushing frequency and mouthwash use.

The scientists found that suffering from bleeding gums, using mouthwash or brushing teeth more frequently didn't significantly change a person's chances of survival.

Nevertheless, the Dr Jason Tasoulas, the study's author stresses that good oral health is necessary to avoid losing teeth. "Maintaining a healthy dentition relies heavily on brushing twice [daily], using floss or interdental brushes, and attending regular dentist appointments (at least every six months)," he told *BBC Science Focus*.

Head and neck squamous cell carcinoma is the sixth most common cancer in the world. It's often caused by tobacco use and alcohol consumption.

"Going to the dentist more often increases your chances of being diagnosed with cancer early, catching the disease at a less-deadly stage and providing crucial time for treatment"

"Our hope is that these findings become a standard part of guidelines implemented for the prevention and management of head and neck squamous cell carcinomas in the near future," said corresponding author Dr Antonio L Amelio.

GEOLOGY

DISCOVERY TRIGGERS HUNT FOR PLANET'S PINK DIAMOND-FILLED SCARS

Geologists locate the missing 'ingredient' that causes rare diamonds to rise to the surface

Pink diamonds once burst from the seams of the Argyle volcano in Western Australia. So much so, that they were mined there. But scientists never knew why so many could be found at that spot, until now.

A new study, published in *Nature Communications*, shows that ancient land 'stretching' during the break-up of the world's first supercontinent, Columbia (also known as Nuna), opened gaps in the Earth's crust. These gaps, created 1.3 billion years ago, caused pink, diamond-rich magma to shoot up and cool at the surface.

Argyle sits in the middle of two landmasses that collided to form what we now know as Australia. "That sort of collision creates a damaged area or 'scar' in the land that will never fully heal," said the lead researcher Dr Hugo Olierook.

When the Nuna supercontinent later split, the Australian landmass didn't break, but instead stretched – crucially along this collision line. With the scar (now transformed into a stretch mark) reopened, diamonds could escape from under the volcanic mountain.

While scientists may not be able to recreate continental stretching to produce more pink diamonds, knowing the third essential process in their formation may help to locate potential mines with similar geological conditions to Argyle.

1. The Argyle volcano in Western Australia was once so full of rocks rich in rare pink diamonds that it was considered to be bursting at the seams with the precious stones.

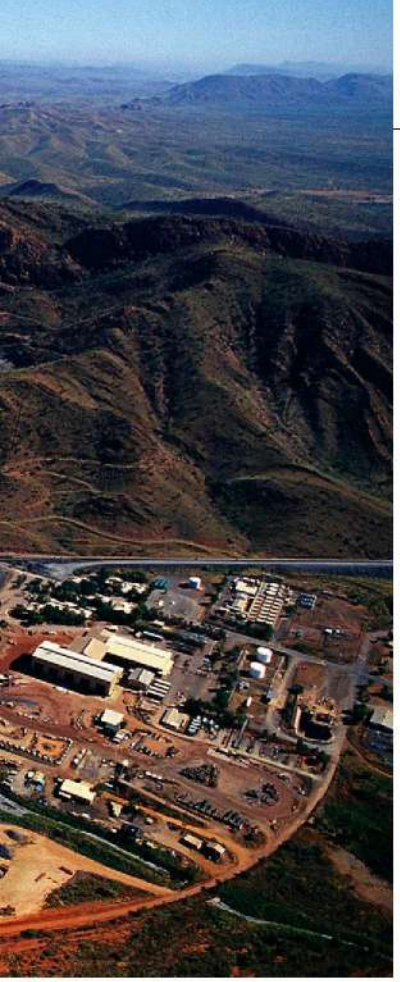
2. Researchers from Curtin University, Australia, used lasers to analyse minerals in rocks from Argyle. They discovered that the volcano is 1.3 billion years old (100 million years older than previously thought), placing Argyle at the geological heart of a key moment in Earth's history.

3. Around 90 per cent of the world's pink diamonds come from the Argyle volcano. It also used to be the world's largest source of natural diamonds, but the mine was decommissioned in 2020.

4. For diamonds to form, carbon must be present in deep underground rocks. Usually colourless, diamonds need the forces of colliding tectonic plates to turn pink. Now, scientists know that continental stretching is the third 'ingredient' needed to bring the diamonds to the surface.

5. "As long as these three ingredients are present – deep carbon, continental collision and then stretching – then we think it'll be possible to find the 'next Argyle'," said the study's lead author, Dr Hugo Olierook. The edges of ancient continents are often covered by sand and soil. This means there may be similar pink-diamond volcanoes around the world that haven't yet been discovered.

MURRAY RAYNER/RIO TINTO X3, GETTY IMAGES, ANDREAS ZAMETZER/CURTIN UNIVERSITY



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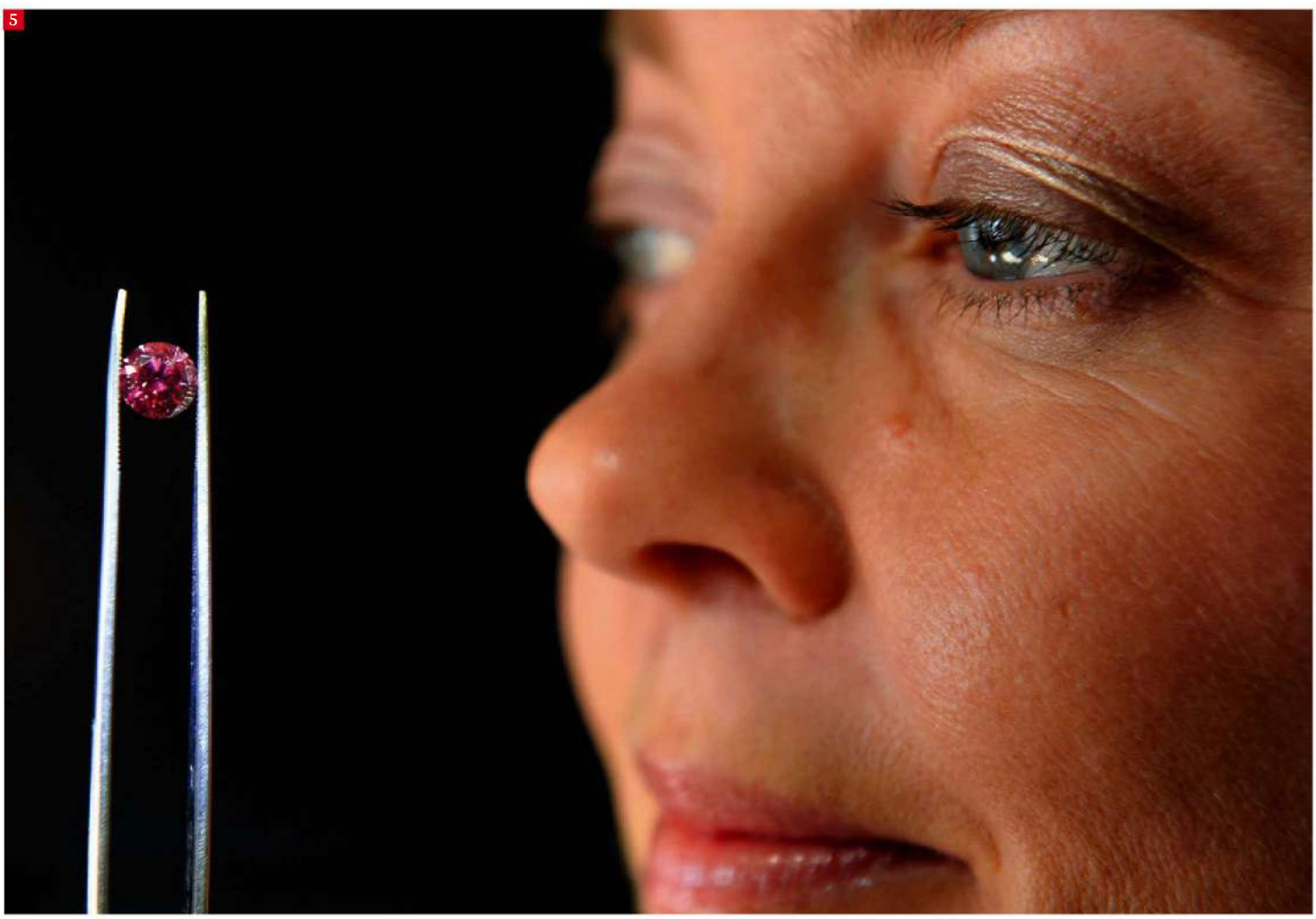

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PRIMER

THE PIROLA COVID SUBVARIANT

The Pirola subvariant of coronavirus has hit the UK. Will it cause more severe disease? Will vaccines protect us? And could it lead to more lockdowns?

Concern over a new strain of the COVID-19 coronavirus, labelled BA.2.86 and unofficially dubbed Pirola, is growing after it was designated a variant under monitoring by the World Health Organization.

At the time of writing, in early September, a few dozen cases had been confirmed worldwide. But what threat might this new variant pose? We asked Prof Paul Hunter, an expert on emerging infectious diseases at the Norwich Medical School of the University of East Anglia, for the lowdown.

WHAT IS BA.2.86 AND WHY IS IT A VARIANT UNDER MONITORING?

It's a daughter of BA.2, an Omicron subvariant that appeared in November 2021. Pirola features more than 30 mutations not seen in BA.2. A year ago, we'd have said that anything with so many mutations is probably something we should be really concerned about. In the case of BA.2.86, however, most of the mutations have already been seen in other variants. So we already know a certain amount about it.

You can't say that, just because it has so many mutations compared with BA.2, it's really scary. It may or may not be, and I'll say this repeatedly: we just haven't seen enough cases yet to really nail any of this down.

DO WE KNOW WHERE BA.2.86 CAME FROM?

Not a clue. Cases were initially identified in Israel and Denmark, but I don't think anybody believes it first appeared in those places. I've heard some people suggest that it might have emerged in Africa, possibly in the south. But we just don't know.

COULD BA.2.86 CAUSE MORE SEVERE DISEASE THAN PREVIOUS VARIANTS?

That's the big question. And by severe disease, we mean being so sick that a sufferer needs supplementary oxygen or to be admitted to hospital; not just a really bad head cold that leaves you feeling drained for a few days.

The problem is that there haven't yet been enough reported infections to tell us anything about the symptom profile. But what we have seen with each successive wave of new variants since the appearance of Omicron back in November 2021 is that, by and large, each has caused less-severe disease than earlier variants.

There are good reasons for that. First, most of us in the UK have already had at least two infections of COVID-19. And second, if you've been vaccinated and you've also had an infection, which many of us now have, you've got what's called hybrid immunity. That provides really good protection against severe disease.

I expect that to be the case with this variant, too. But again, until we've seen more cases, we can't be definitive.

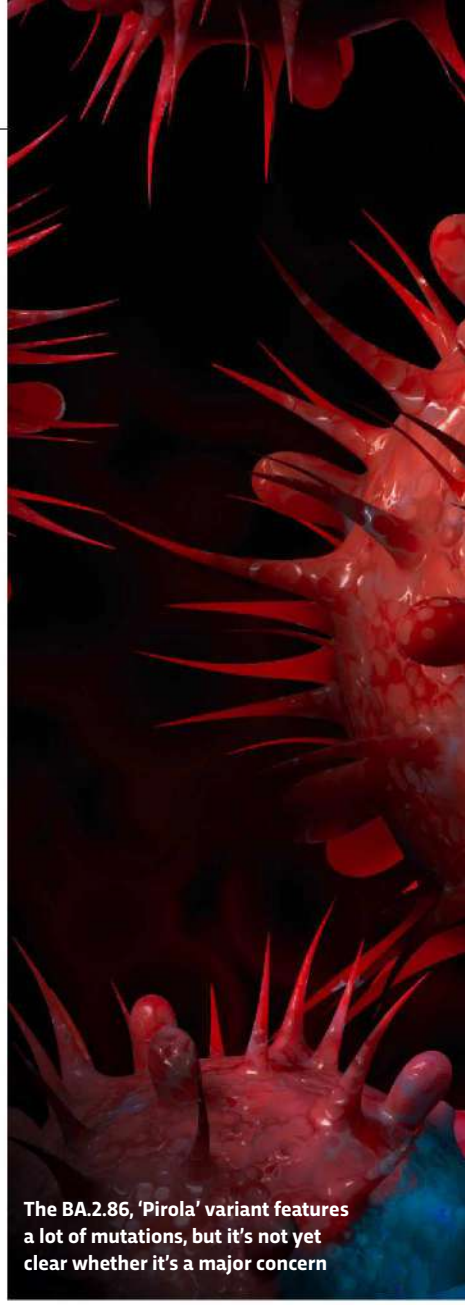
HOW TRANSMISSIBLE IS BA.2.86?

There are two issues that affect transmissibility. The first is how intrinsically transmissible a virus is. The second is how easily a virus is able to evade immunity. So if you've got a very highly transmissible virus, but everybody's immune, it's not going to spread. Equally, if you have a virus that's not very transmissible, but [nobody has been vaccinated against it], then it will spread.

BA.2.86 does seem to have an advantage in evading immunity and vaccines compared with BA.2, but only at the level that we've also seen in other variants recently. It looks as if it's not very much more transmissible than the EG.5.1 variant (also known as Eris), which peaked sometime in late July or early August, and which now seems to be on the decline.

WILL THE CURRENT VACCINES BE EFFECTIVE AGAINST BA.2.86?

Forgetting about BA.2.86 at the



The BA.2.86, 'Pirola' variant features a lot of mutations, but it's not yet clear whether it's a major concern

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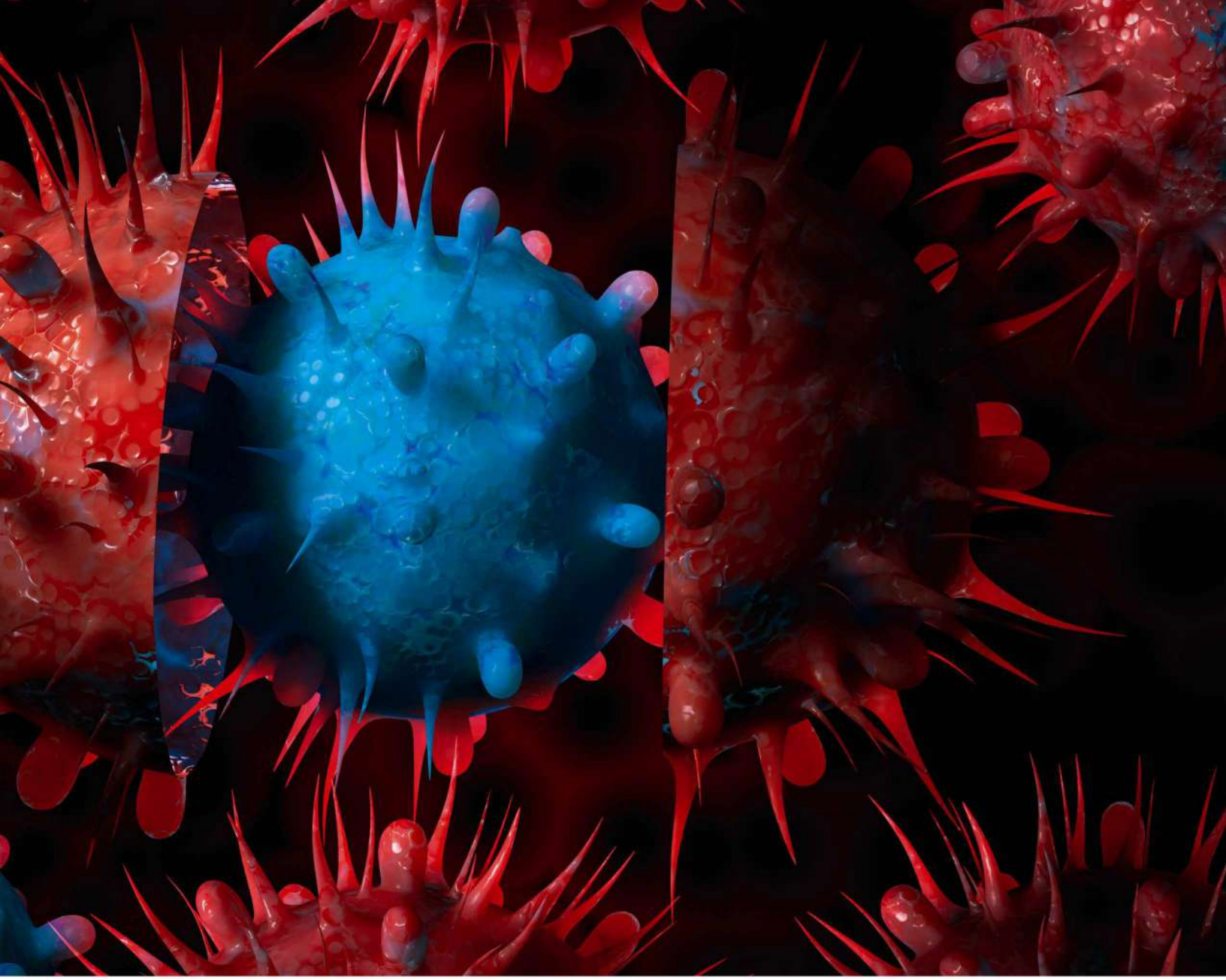


moment, the current vaccines generally provide immunity against infection for only four to six months. And your immunity starts to wane a couple of months after you've received a booster.

We no longer rely solely on the vaccine for immunity from COVID-19, however. For the vast majority of us, our immunity is the result of a mixture of prior infection and vaccination. Prior infection provides better immunity to severe disease than vaccination. But neither provides very durable immunity to reinfection.

This means, though, that if you do get reinfected with COVID-19, you're a lot less likely to end up in hospital. As it stands at the moment, vaccines will probably be no less effective against this variant than they have been against EG.5.1.

NOW THAT WE'RE HEADING INTO AUTUMN AND WINTER – TYPICALLY A PERIOD WHEN INFECTIONS RISE – IS THERE A POSSIBILITY OF MORE LOCKDOWNS?

In medicine and epidemiology, you never say never. But I think it's extraordinarily unlikely that we would want to implement any further restrictions like that.

The people making these decisions are trying to balance the benefits against the hazards. Until Easter 2021, the benefits of what we call non-pharmaceutical interventions probably outweighed the harms that they did. Since then, though, the harms have probably outweighed the benefits.

Viruses that cause repeated infections generally level out at what's called the endemic equilibrium – the average level of infection over the course of the year.

Most of these viruses are seasonal, so most infections tend to occur between November and February, then drop during the summer.

With modelling you can show that, once a virus has approached the equilibrium, these sorts of non-pharmaceutical interventions don't really drive down infections. What *does* affect infections is the rate at which immunity is lost.

Further lockdowns would bring with them considerable harm, as they did in the first year, but probably wouldn't bring many benefits now. So I can't see them happening again with this virus.

PROF PAUL HUNTER
Paul is professor in medicine at the Norwich Medical School of the University of East Anglia, where he studies emerging infectious diseases.

COMMENT

LOOKING TO LOSE WEIGHT? EXERCISE ALONE WON'T WORK

Want to shed that spare tyre? It's not as easy as it seems. Trust me, I cycled the length of Britain to try

I turned 50 this year. To celebrate, I decided to cycle from Land's End to John o'Groats – just over 1,600km (994 miles). I cycle to and from work each day, about 44km (27 miles), so felt I had enough base fitness to tackle the challenge. And I could stand to lose a few pounds, too.

So far, so midlife crisis.

Scouring the internet, I found Pedal Britain, a company that offers fully supported 'end-to-end' tours – moving bags, organising accommodation and, crucially, providing food during the day. All I'd have to do was pedal about 120 hilly kilometres (75 miles) a day for 14 consecutive days. Easy!

I signed up in December 2022 for a July 2023 ride, leaving just over six months to prepare. The cold, dark days of winter eventually gave way to spring daffodils and, before I knew it, I was at London's Paddington station on a sunny mid-July morning to catch the train to Penzance.

That evening I joined the other 15 members of the group at the Longboat Inn for the pre-tour briefing. We represented an eclectic slice of society, everyone joining for very personal reasons: newly retired, newly divorced, midlife crises and so on.

When lead guide and company owner Darren stood up, the room fell silent. He went over logistics, daily schedules and safety, then got to fuelling. I am, professionally (I study the brain's control of appetite) and recreationally (I love food), very interested in all things food-related.

Darren was crystal clear that energy bars and sugar gels consumed on the move would not suffice for such a prolonged effort. We would need to eat real food, and often. The 1,600km would be broken down into roughly 32km (20-mile) sections, with two or three stops each day. There would be food at each stop, and we would actually sit down to lunch.

PROF GILES YEO

(@GilesYeo)

Giles Yeo is a professor at the University of Cambridge researching food intake, genetics and obesity. He is also a broadcaster and author, and his latest book is Why Calories Don't Count *(£10.99, Orion)*

"It was shocking to do something so extreme and see no difference in weight"

We were exhorted to eat at every stop, particularly over the first four days as our bodies got used to the exertion. If not, we would likely end up in the support van on day five. Darren assured us that by day seven we would be fitter and more efficient, so would begin to need less food.

It seemed so unlikely. Cycling into fitness? Really?

At 6.30am the next day, the first batch of 'magic numbers' pinged onto the tour WhatsApp group: Morning stop, 21km (13 miles), Marazion station car park; Lunch stop, 60km (37 miles), Linden Hey tea rooms; Day-one finish, 97km (60 miles), St Austell Premier Inn. That 6.30am ping would be our clarion call over the next 14 days.

After breakfast, we were transported to the start, then – after the customary picture under the Land's End sign – we were off. The first stop, at a relatively paltry 21km, yielded a feast: bread, cheese, salami, mini scotch eggs, pork pies, bananas, nuts, dried fruit, fig rolls, cookies and jelly babies.

Some 20 minutes later we were off again, up and down steep country lanes until lunch at 60km. There we devoured sandwiches, crisps and cakes, before the final 37km to St Austell – the last 16 ridden in the pouring rain. I arrived wet, cold, tired and inexplicably hungry, given that I'd already had three meals that day. That evening I ate a three-course dinner, returned to my room and collapsed into bed.

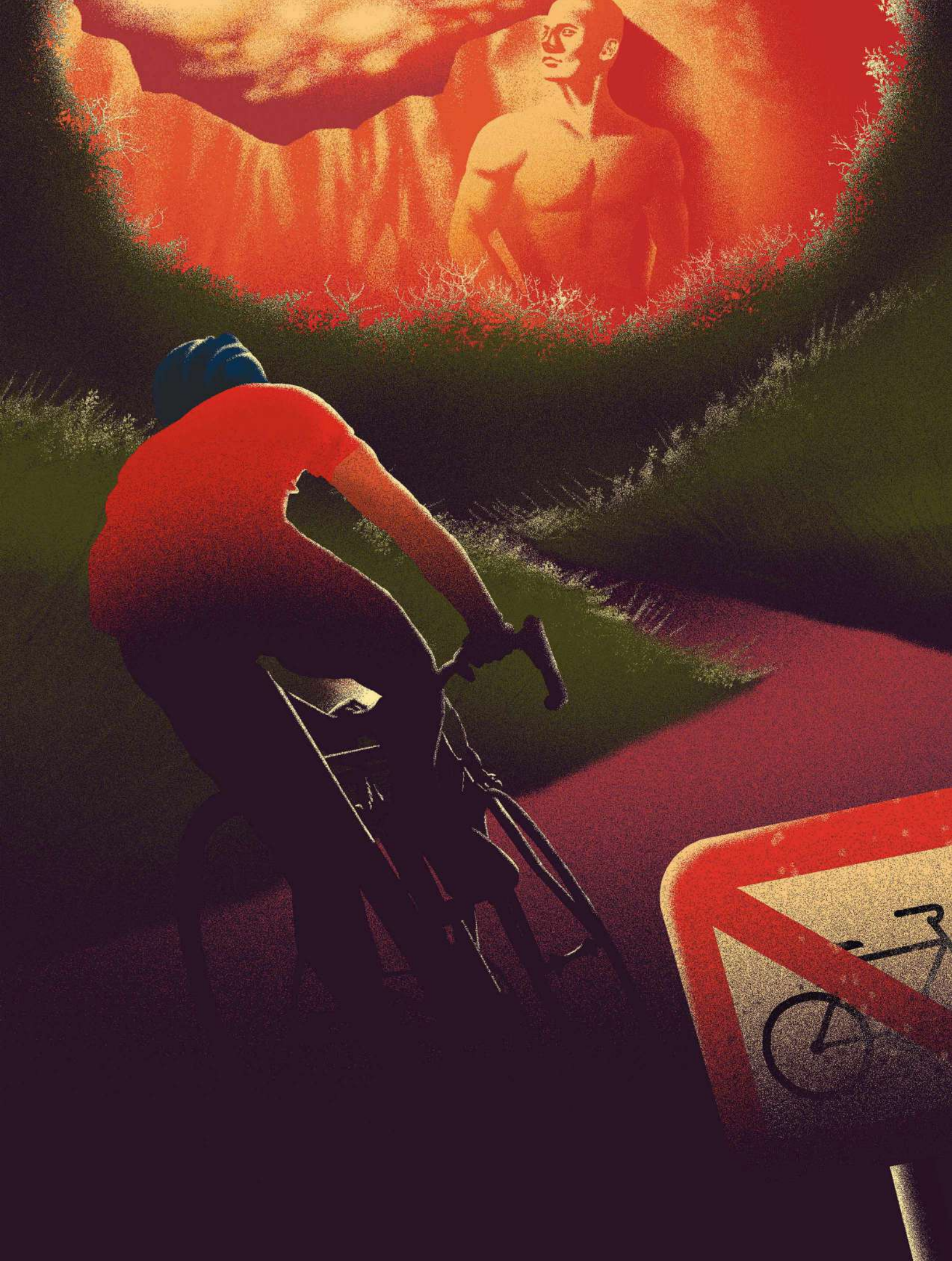
Darren was correct, of course. I had a phenomenal appetite that first week, eating five times a day, because I was so hungry. Then, amazingly, my legs did indeed come back to me, and I began to eat less (relatively speaking). Finally, after two weeks of riding, we rolled into John o'Groats, tired and elated.

What of my weight after 14 days and 1,600km? I'd started the ride at 80.9kg (178lbs). When I got home, I stood on the scales and weighed (drum-roll)… *exactly* the same. I hadn't lost a single gram.

It was deeply disappointing, but not unexpected. We've long known that exercise alone is not effective for weight loss. Nevertheless, it was still shocking to do something so extreme and see no difference. It is, of course, possible to lose weight through exercise. Tour de France cyclists eat around 5,000 kilocalories a day, yet still lose weight during the three-week race. The problem is that most of us don't exercise enough to achieve that. According to my heart-rate monitor (with the caveats that entails), I was burning an additional 3,000 kilocalories or so each day – for which I clearly compensated with my increased food intake. As I discovered, exercise makes you very hungry indeed.

After two weeks of intensive exercise, although I didn't lose any weight, I am undeniably fitter and, according to my wife, my moobs have shrunk. This means I'm carrying more muscle. Your weight (and this bears repeating) is just a number on a scale. It doesn't tell you how fit or healthy you are.

ILLUSTRATION: BERNARD LEONARDO



COMMENT

ACCUSING ORCAS OF ATTACKING BOATS TURNS THEM INTO VILLAINS

We need to learn a lot more about whale behaviour before we can say if they really are out for revenge

A French sailor named Lou told me, recently, about his frightening encounter with a group of orcas, or killer whales. The majestic marine mammals displayed some troubling behaviour: five of them approached the yacht he was sailing and then rammed the hull, spinning the boat around repeatedly.

The incident lasted 80 minutes and left the small sailing vessel's rudder split in two. The orcas then appeared to toy with the floating foam that was leaking from the broken rudder, pushing it around with their noses.

In the shipyard, Lou described the encounter. "It looked like the orcas were playing," he said, "and that they were training each other."

This was just one of a series of incidents that have been making news headlines recently. And that's because a population of Iberian orcas in the Atlantic ocean have, over the past few years, developed a strange habit of 'attacking' boats.

"Orcas are complex, intelligent animals with culture and deep familial bonds"

VICTORIA GILL

Victoria is BBC News's award-winning science correspondent. Her reporting can be found on television, radio and online.

ILLUSTRATION: ADRIA VOLTA

I thought that Lou's account was remarkably thoughtful, under the circumstances. Especially as he never referred to it as an 'attack', only an 'encounter'. Similarly, another sailor I spoke to described his experience with killer whales as a "dance with my orca friends".

You may have seen headlines employing alarming and emotional language to describe the behaviour of this population of marine mammals. The term 'attack', for example, suggests an aggressive assault. And some reports have suggested that these animals, which move through one of the world's busiest waterways hunting for tuna, are seeking revenge on boats.

There's no shortage of cases of marine mammals being harmed by boats, injured by propellers or fishing gear, or affected by the chronic noise from shipping activity that can affect their ability to feed and communicate. But creating a narrative in which these orcas are portrayed as angry, vengeful or bent on teaching humans in fragile sailing boats a lesson is, at best, unwise and, at worst, dangerous. In doing that, we're telling a story in which humans are on one side of a battle, with orcas on the other.

Conflict between people and wildlife is not just material for enticing headlines. It is, according to the International Union for the Conservation of Nature, a serious threat to our efforts to co-exist with the natural world.

Researchers from Spanish conservation organisations have now asked sailors to submit videos of any encounters with these killer whales so that they can study their behaviour and work out whether this risky new habit is spreading through the orca population.

Scientists in Tarifa in southern Spain, close to where many of these incidents have been reported, are also setting out to track the animals with GPS tags. This is more invasive research, but it is yielding real-time data about where the orcas are.

When I first reported on the Iberian killer whales' unusual new behaviour, I spoke to neuroscientist Dr Lori Marino, president of the Whale Sanctuary Project – and one of the few people to have seen inside the brain of a killer whale, having scanned the brain of a deceased captive orca for a study back in 2004.

"Parts of their brains – like the limbic system, which you can think of as the emotional processor – they share with us," she explained. "So they probably do experience anger, grief and joy. But if we try to say that these social, intelligent, playful animals are solely good and peaceful, or solely bad and aggressive, we're turning them into caricatures."

We can't look inside of mind of a living orca, but we do know from studies of their behaviour and their brains that these are complex, intelligent animals with culture and deep familial bonds.

We have information and scientific tools at our disposal to find out how best to navigate this strange new situation. We can see signs of playfulness in their behaviour. And we can see that the survival of this specific population is directly linked to stocks of tuna in that region.

We could use that information to manage fisheries. We can even tag and track the animals (providing we're not harming them) so we can take on the responsibility of keeping our distance.

When I left Lou the sailor and his crew mates in the Spanish shipyard, all he wanted to know was where the orcas were most likely to be so that he could leave them in peace (and avoid any more damage to his boat).

Though we can't understand the orcas' motivation, and we certainly can't control their behaviour, we can use all the data we gather on them to help keep ourselves, and our boats, a safe distance from them.

So let's not cast wild animals as our enemies. We already have enough problems co-existing with nature without turning a complex situation into a battle of us versus them.

REALITY CHECK

THE SCIENCE BEHIND THE HEADLINES

COVID boosters | A new force | Salt

REVIEW

COVID BOOSTERS: ARE THEY ENOUGH TO PREVENT A WINTER SPIKE IN INFECTIONS?

As new variants of coronavirus continue to emerge, the next round of vaccinations has started in a bid to protect the most vulnerable people

"If the uptake of the booster is low in the vulnerable population, a rise in severe infections and hospitalisations will probably follow"

BBC *For more fact-checking news, visit the BBC's* Verify *website at* ***bit.ly/BBCVerify***

As the new COVID-19 subvariant, BA.2.86, nicknamed Pirola (see page 26), spread across the world, the UK Health Security Agency decided to bring the start of the booster vaccination programme for the most vulnerable people forward to 11 September.

BA.2.86 was first identified in Denmark on 24 July, before turning up in Israel, the UK and the US. At the time of writing in early September, more than 30 cases of Pirola had been detected in England, 28 of which were in a Norfolk care home. But how effective are booster jabs at combatting new variants like this and should we all be getting them?

SHOULD WE ALL BE GETTING A BOOSTER JAB?

For most people, getting a COVID-19 booster is a good idea. But not everyone will be eligible for one in this latest round of vaccinations.

The Joint Committee on Vaccination and Immunisation has recommended boosters only for certain people, including the clinically vulnerable, those aged 65 or over, residents in care homes for older adults, frontline health and social care workers, and people who live with or care for certain clinically vulnerable individuals.

Boosters are recommended for such people because they're at heightened risk of suffering severe illness from COVID-19 infection. Fading protection from previous jabs, coupled with the rapid spread of current variants, such as Eris, and the emergence of new concerning variants, such as Pirola, will likely lead to a spike in infections this autumn.

The COVID-19 booster, just like the seasonal flu vaccine, is very effective at reducing the likelihood of severe infections and hospitalisations, as vaccinations did in previous years.

Most individuals eligible for the COVID-19 jab will also be able to get a flu jab at the same time, providing added protection over the autumn and winter when transmission of such infections is highest.

The current guidance doesn't mandate boosters for the rest of the population, however, despite the fact that anyone can become seriously ill with COVID-19, and even mild cases can lead to the months-to-years-long, often-severe condition known as long COVID.

Whether you will or won't be receiving a booster, it's important to remember that FFP2/3 face masks, good ventilation and avoiding crowded indoor spaces have all been proven to significantly reduce the chances of virus transmission.

WHAT TYPE OF COVID BOOSTER JABS WILL BE AVAILABLE?

Most people will be offered one of the two bivalent mRNA vaccines that immunise against the original strain of SARS-CoV-2 and the Omicron variant. Both the Moderna Spikevax and Pfizer/BioNTech Comirnaty vaccines should be available, though people under 18 can only receive the Comirnaty vaccine. Both vaccines are similarly effective at preventing severe illness.

WOULD A LOW UPTAKE OF THE VACCINE CAUSE A PROBLEM?

Cases of COVID-19 are already rising again and, with new variants emerging, it's very likely that we'll see a significant number of cases this autumn and winter. If the uptake of the booster is low in the vulnerable population, a rise in severe infections and hospitalisations will probably follow.

Unfortunately, without boosters for all and attention to personal preventative measures, increasing cases will affect many in the population, not just the vulnerable, resulting in more illness and more cases of long COVID.

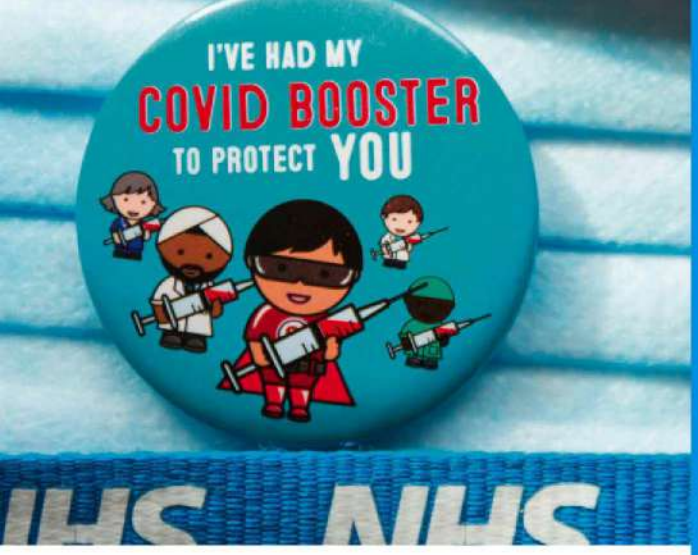
WILL THE VACCINES WORK ON NEW COVID VARIANTS, SUCH AS ERIS AND PIROLA?

Vaccines are less effective at preventing infection by many of the new variants. They do, however, remain quite effective at reducing severe infections and hospitalisations, which are the driving forces behind the government's vaccine recommendations.

This is also the likely situation for the new Eris and Pirola variants. We don't have all the data yet to know exactly how well the bivalent mRNA boosters will perform, but it's likely they'll continue to offer protection against severe COVID-19 infections.

The wrinkle is that both Pfizer/BioNTech and Moderna have updated versions of their mRNA vaccines that include the recent XBB variant of Omicron, which would likely offer more significant protection against the current variants. Unfortunately, these vaccines are yet to be licensed, but they'll be made available if and when they're approved. →

ALAMY



ABOVE People who live with or care for clinically vulnerable individuals are encouraged to get a booster this autumn

→ HOW MUCH OF A PUBLIC HEALTH RISK IS COVID NOW?

COVID-19 remains a significant public health risk. We all want to be able to move on from the pandemic, and the summer lull in cases has given us the false impression that we can.

Unfortunately, the virus is still with us and cases are rising again. We know that immunity from a previous infection as well as vaccination can help protect against subsequent infection and severe illness, but studies show that immunity doesn't last. So, just as earlier on in the pandemic, the elderly and clinically vulnerable are at high risk of severe illness.

COVID-19 is still a risk to everyone, though. Studies show that around 10 per cent of all cases – even very mild ones in healthy young adults, lead to long COVID – for which we have no proven treatments. Thankfully, between vaccines and personal preventative actions, we have lots of ways to protect ourselves from infection.

HOW CAN YOU DECIDE WHETHER OR NOT TO GET A VACCINE BOOSTER?

When deciding whether you should get the COVID-19 booster, it's best to start by considering the risks to both yourself and others if you don't get the vaccine, which range from severe disease to long COVID.

Then consider the risks of the vaccine itself. For most people, the jab results in a day or so of mild soreness, fatigue and fever. More severe side-effects are rare – certainly far rarer than complications resulting from the disease itself. Some people have had adverse reactions to past COVID-19 vaccines, however. If that's you, discuss the booster with your GP.

For people with previous or ongoing long COVID, studies have shown that the vaccine can affect the disease in various ways – improving symptoms in some, making them worse in others. These individuals must try to balance the risks of being reinfected against the potential effects of vaccination on long COVID.

by **DR JEREMY ROSSMAN**

Jeremy is an honorary senior lecturer in virology and president of Research-Aid Networks at the University of Kent.

ANALYSIS

A NEW FORCE: PHYSICS MIGHT SOON NEED AN UPDATE

New measurements of subatomic particles interacting with magnetic fields hint at physics beyond the Standard Model

On 10 August, an international collaboration of scientists at the Fermi National Laboratory (Fermilab) on the outskirts of Chicago announced an updated and more precise measurement of the way muons interact with a magnetic field.

The update was eagerly awaited, largely because previous measurements disagreed with the predictions of the Standard Model of particle physics. The discrepancy has led to talk of a possible fifth force of nature. But what would that mean, and what did the update tell us?

There are four known fundamental forces: gravity, the electromagnetic force, the strong nuclear force and the weak nuclear force.

Gravity is described by relativity; the other three are encompassed by the Standard Model of particle physics. A fifth force would be something beyond this and, as such, would be a huge breakthrough in our understanding of the physics behind the world we live in.

Physicists are hungry for such a breakthrough because, although the Standard Model is a beautiful way of explaining a vast array of phenomena, it's not a complete 'Theory of Everything'.

For example, as mentioned above, it doesn't contain gravity; in fact, relativity and the Standard Model are inconsistent at very high energies. Any measurement that doesn't agree with the current theory would be seen as a clue to what a bigger and, hopefully, better (in the sense of being more explanatory) theory might be.

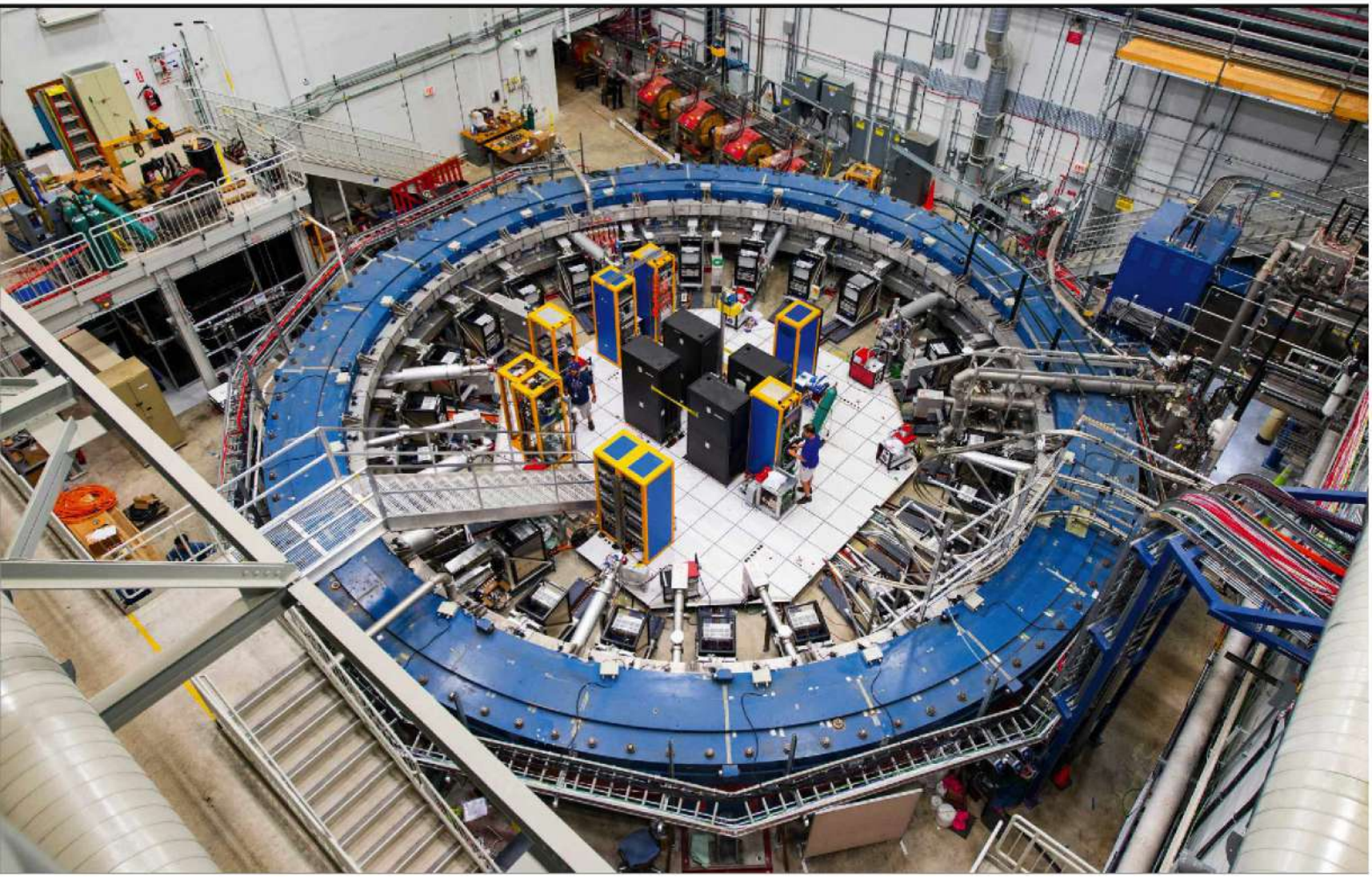
Now, it seems, such a breakthrough might be on the horizon, thanks to Fermilab's experiment with muons. Muons are fundamental particles, according to the Standard Model, which is to say they're one of the basic building blocks of matter. A muon is very much like an electron, but about 210 times heavier.

Muons carry electric charge and have angular momentum known as spin. That means that they have a tiny magnetic moment: an axis with north and south poles, like a bar magnet or the planet Earth.

The experiment at Fermilab corrals billions of muons into a storage ring, governed by very accurately calibrated electric and magnetic fields, and measures how their magnetic axes wobble – or precess – as they travel around the ring.

ALAMY, REIDAR HAHN/FERMILAB

“A fifth force would be a huge breakthrough in our understanding of the physics behind the world we live in”



These wobbles can be calculated very precisely in the Standard Model. The calculations involve so-called ‘virtual’ particles, which aren’t directly observed, but which influence the results by making fleeting appearances in quantum loops.

If the measurements don’t line up with the prediction, that could be a sign that there’s an unknown particle appearing in these loops.

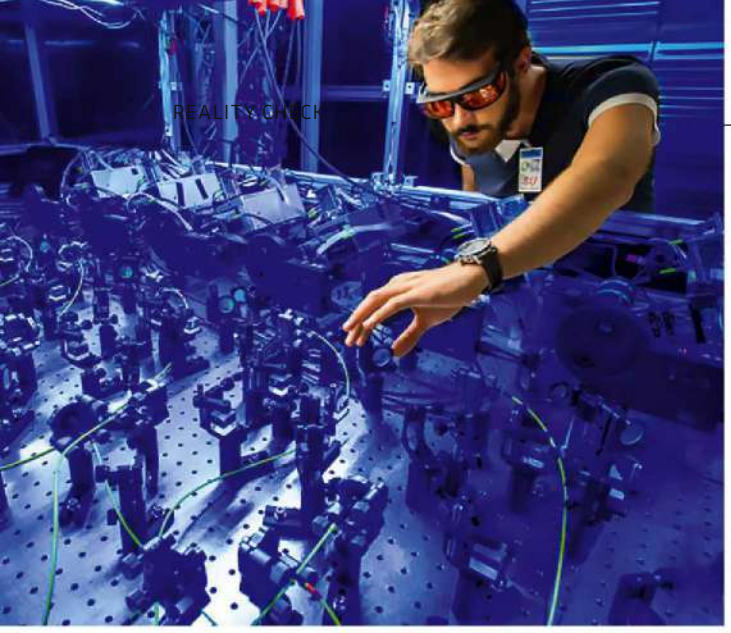
One favoured candidate for such a particle would be the carrier of a fifth force. This would be equivalent to a photon, which carries the electromagnetic force, but wouldn’t be part of the Standard Model.

Fermilab’s updated measurement of the muon’s magnetic moment is an impressive achievement because it confirms the previous value at significantly higher precision. But there are two big issues to be resolved before we could say we have discovered a fifth force.

ABOVE The magnetic field generated within this ring at Fermilab was used to precisely measure the ‘wobble’ of muons

First, the measurement is so precise it challenges the precision of the theory. The discrepancy is based on a widely agreed combination of theoretical calculations, but there are some newer predictions that are closer to the measurement than this and not all of the predictions are consistent with each other.

These differences may themselves be a sign of some interesting new physics, but they certainly need to be resolved before we can be sure we’re seeing any kind of fifth force. →



ABOVE Paulo Girotti, a researcher at Fermilab, works on the equipment used for the muon experiment

→ The second issue is more subtle, but more exciting. If the discrepancy is confirmed, we'll be sure that there is something new going on, even though we won't be sure exactly what it is.

The ideal outcome would be that the discrepancy would inform new theoretical ideas and that these would lead to new predictions – for example, how we might find the particle that carries the new force, if that's what it is.

The final confirmation would then come from building an experiment to directly discover that particle – much like the ideas of Robert Brout, François Englert and Peter Higgs were finally vindicated only with the discovery of the Higgs boson.

There are other experiments making measurements that challenge the Standard Model. Several discrepancies exist in various measurements from experiments at the CERN Large Hadron Collider (LHC), for example. But some discrepancies are bound to crop up as we explore new territory in physics, and many such anomalies have later vanished as we collected more data and gained a better understand the experiments from which they emerged.

There will be an even more precise update from Fermilab in due course, and the LHC will also collect a lot more data over the next few years. Physicists working there will be continually watching for discrepancies that don't go away, based on a multitude of new and more precise measurements.

Nevertheless, the muon magnetic moment is one of the longest-standing and most significant discrepancies between any measurement and the Standard Model. The measurement itself is very unlikely to be wrong. Which means that, if the theory predictions get sorted out, this could be the first strong evidence for something new and beyond the Standard Model – possibly a fifth force of nature.

by **PROF JON BUTTERWORTH**

Jon is a Professor of Physics at University College London. He works on the ATLAS experiment at the CERN Large Hadron Collider.

COMMENT

SALT: EATING LESS CUTS YOUR RISK OF HEART DISEASE BY 10%

Salt helps food last longer and taste better, but too much of it can be a danger to your health

We love the taste of salt, which is fortunate because we need it.

The salt we sprinkle on our chips or scrambled eggs is sodium chloride. Both sodium and chloride are essential nutrients. We get chloride from various foods, but we mostly consume sodium in the form of salt. We need both elements for critical body functions such as the firing of nerves and muscles, and maintaining fluid balance. If your sodium levels get too low, you might suffer cramps, nausea, vomiting or dizziness, and – in extreme cases, if the deficiency goes untreated – shock, coma and even death.

But consuming too much sodium also causes problems. It can lead to fluid retention in the blood, which causes high blood pressure. That, in turn, puts stress on the blood vessels and organs, increasing the risk of stroke, blood-vessel diseases, heart attacks and kidney disease.

Most people in the western world eat too much salt. Adults typically need less than 2g each day for our essential needs and the World Health Organization (WHO) recommends a daily maximum of 5g – less than a teaspoon. Yet in the UK, the average daily consumption is over 8g. This overconsumption of the simple mineral contributes to thousands of strokes, heart attacks and deaths every year.

About a quarter of our salt intake comes from what we add when cooking or when we season our food at the table. We do this mostly because salt makes everything taste better, enhancing flavour and blocking bitter tastes.

Even though it makes up only a fraction of the total salt we eat, reducing the amount we sprinkle on our food can still result in significant health benefits.

A recent study carried out by Dr Yoon Jung Park, of Kyungpook National University Hospital, South Korea found that a simple change in habit (adding salt only usually, instead of always) can reduce the risk of certain heart diseases by over 10 per cent.

Sensitivity to salt varies significantly between people. This is partly due to genetics, but acclimatisation also plays a role, depending on our regular eating habits. It might even be influenced by how much salt our mothers ate while each of us was in the womb.

The good news is that, if we reduce the amount of salt we add to our meals gradually over the course of a few weeks, our taste buds can slowly adapt to that change, making it fairly easy to adjust to a diet with less salt.

REIDAR HAHN/FERMILAB, GETTY IMAGES

"Overconsumption of the simple mineral contributes to thousands of strokes, heart attacks and deaths every year"

Other ways of reducing salt consumption include switching to a finer grind (using smaller salt granules) and only adding salt to the outside of food (when it has been served, rather than when it's being prepared). Doing the latter allows it to meet the taste buds more quickly, producing a stronger salt 'bump' despite the smaller amounts involved. Adding herbs to food is also a good way to enhance its flavour without adding large quantities of salt.

It pays to pick your battles, though. Lots of very healthful foods, such as vegetables, are innately bitter. Don't let reducing your salt intake result in also reducing your consumption of vegetables.

But where does all the extra salt we consume come from? It's hidden in processed and packaged foods. Salt is often used as a preservative, dramatically extending the shelf-life of ready-made foods. By a process of osmosis, added salt draws water out of the cells of microbes, reducing the ability of bacteria and mould to grow and spoil food.

But salty-tasting foods, such as crisps, processed meats and other savoury items, aren't the only things that contribute to excess salt intake. Some shelf-stable sweet products (think cakes, cookies and muffins) can also incorporate large amounts of salt.

Ready meals can also be high in salt even if they look like balanced meals. Many low-fat and low-sugar versions of products include more salt to boost their flavour.

Much of the confusion is down to labelling. Instead of listing the food's salt content, labels list its sodium content, which is only one of the chemical constituents of salt. Thus the 5g or less of salt recommended by the WHO is equivalent to just 2g of the sodium listed on the label.

In recent years, plain table salt has been joined on shop shelves by several other varieties: sea salt, pink salt and Himalayan salt, to name just a few. These products often claim to provide health benefits, due to the additional minerals they contain. Ultimately, though, they're still high in sodium and can cause the same health outcomes as table salt when overeaten.

The bottom line is that every reduction in your salt intake can help reduce the risks to your health. It's never too late to start cutting down if you're eating more than the recommended amount. So, next time you're cooking or sitting down to eat, think twice before reaching for the salt shaker. SF

by DR EMMA BECKETT

Emma is a food and nutrition scientist and registered nutritionist who works as a senior lecturer at the University of Newcastle, Australia and at Nutrition Research Australia.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

REVIEW

FAIRPHONE 5

The smartphone that's built to last longer than any other **p40**

RECOMMENDED

AI TOOLS

Our pick of the top 10 labour-saving artificial intelligence apps **p42**

NEW TECH

IDEAS WE LIKE

Our pick of this month's greatest new gadgets **p44**

Polaroid's newest instant camera packs in the tech **p45**

37 per cent of people in the UK have used AI tools at work
(Source: Acuity Training)

68 PER CENT
of large UK companies use at least one AI tool
(Source: Forbes)

$119.78 Billion
The value of the global AI market in 2022
(Source: The Social Shepard study)

REVIEW

Fairphone 5: The obvious choice for smartphone sustainability

The Fairphone 5 might look like a typical smartphone, but it has been built to last a lot longer

In a world of cookie-cutter, carbon-copy smartphones, the new Fairphone 5 stands out. It isn't the prettiest device, nor is it the most powerful. It doesn't even have mind-bogglingly good cameras. Instead, the Fairphone 5 is simply built to last.

Fairphone doesn't want you to trade in your phone for something new in a couple of years. The company would much rather you hold onto your device for as long as possible. To that end, it has made the Fairphone 5 easy to repair, given it a warranty that lasts five years and has promised to support it for far longer than any competing devices.

In fact, from sourcing materials right through to the end-of-life process, the Fairphone 5 is about as sustainable as smartphones currently get. But does this focus on repairability and sustainability mean sacrifices in its abilities? We spent time with the Fairphone 5 to find out.

Much of the Fairphone 5 has been built from recycled and ethically sourced materials

SUSTAINABILITY

In recent years, there has been a major push from tech companies to make their products more sustainable. In an attempt to cut carbon emissions, devices are now being made with more recycled materials and sold with less packaging.

But while most companies are only just beginning to think about sustainability, it has been Fairphone's entire ethos from the start. To that end more than 70 per cent of the Fairphone 5 is made using fairtrade or recycled materials. The battery uses 100 per cent fairtrade gold and responsibly mined lithium, as well as 100 per cent recycled tin in the solder.

The phone's back cover is made using 100 per cent recycled plastics and even the OLED display and speakers are almost 100 per cent fairtrade or recycled.

But it doesn't stop there. Once you take ownership of the Fairphone 5, the sustainability aspect continues in a different manner. The phone is modular, with each part being easily repairable by the user. Fairphone sells replacements for batteries, cameras, screens and just about every bit of the phone on fairphone.com.

"ALTHOUGH EXTRAVAGANCE HAS BEEN OVERLOOKED, IT'S MADE UP FOR BY THE PHONE'S STURDY FEEL"

If something happens to the phone that you can't repair, there's a five-year warranty to cover you, and if you manage to keep your handset going long enough, you'll be backed by security updates all the way up to 2031 – much longer than other smartphone makers promise.

To top it off, for each Fairphone 5 bought, the company will recycle the same amount of electronic waste or give an old smartphone new life. This, in theory, compensates for the production of your smartphone.

It may lack the opulence of some of its rivals, but the Fairphone 5 has a style all of it own

DESIGN

Made from recycled plastic, the back of the Fairphone 5 doesn't look or feel as premium as the metal and glass backs that the likes of Apple, Samsung and OnePlus use for their smartphones.

Although extravagance has been overlooked, it's made up for by the phone's sturdy feel, which removes the fear of drops and breakages you get with those more expensive, glass-backed devices.

While it's by no means ugly, it does have a somewhat dated design. Thick bezels surround the display, and the back resembles the design of some of Samsung and OnePlus's more budget smartphones.

The side features a pretty snappy fingerprint sensor as well as a premium metal frame that extends all the way around the phone.

PROCESSING POWER

The Fairphone 5 might be eco-friendly, but how does its performance stack up against the competition?

In terms of processing power, Fairphone takes a unique approach. It uses the Qualcomm QCM6490 chipset – designed primarily for commercial systems instead of smartphones. Despite smartphones being new territory, it performs just as well as any other mid-range smartphone chip.

It's never going to win any awards and will show signs of lag or struggle in places, but for most examples of gaming or daily tasks, it'll perform perfectly well. It's also the reason that Fairphone is able to offer security updates for so long.

The battery life is about average – it'll get you through a full day of normal usage with nightly charges or top-ups throughout the day needed.

One of the most noticeable differences compared to the previous Fairphone is the display. Now running at 90Hz refresh rate, swiping, scrolling and general movements around the phone feel much smoother.

CAMERAS

Fairphone has put a lot of effort into camera improvements compared to last year's model. Continuing the theme, the phone by no means has the best cameras at this price point, but those it does have will handle most tasks you throw at them with ease.

There are three cameras on the device – wide and ultrawide cameras on the back and a single 50-megapixel selfie camera on the front.

Photos taken at night tend to be a challenge, requiring the steadiest of hands, but the cameras perform much better in well-lit conditions. When outside, the Fairphone 5 secured some fantastic images.

It seems to struggle when using the zoom functions, resulting in some blur, and the camera tends to over-edit photos. This makes most things look better, but is less accurate to life.

Like last year's Fairphone, the selfie camera is weaker. While it can take clear images and is mostly fine, it isn't always the most flattering and can often lose details in shadows or overexpose light.

VERDICT

Finding an eco-friendly smartphone isn't easy, especially one with credentials as impressive as the Fairphone. Is it the best smartphone out there at this price (£649)? No, the likes of Samsung, OnePlus and Apple can offer better.

However, none of these brands come close to matching the Fairphone's repairability, durability or even lifespan. While its competitors will outperform it, they'll be dead long before the Fairphone starts to show its cracks.

Despite lagging behind its competitors somewhat, the Fairphone is by no means a bad smartphone. It has plenty of power, decent cameras and battery, and even a hardy frame. Really, it all feels like a fair trade off for its unique and impressive eco-credentials.

RATING

★★★★☆

PROS

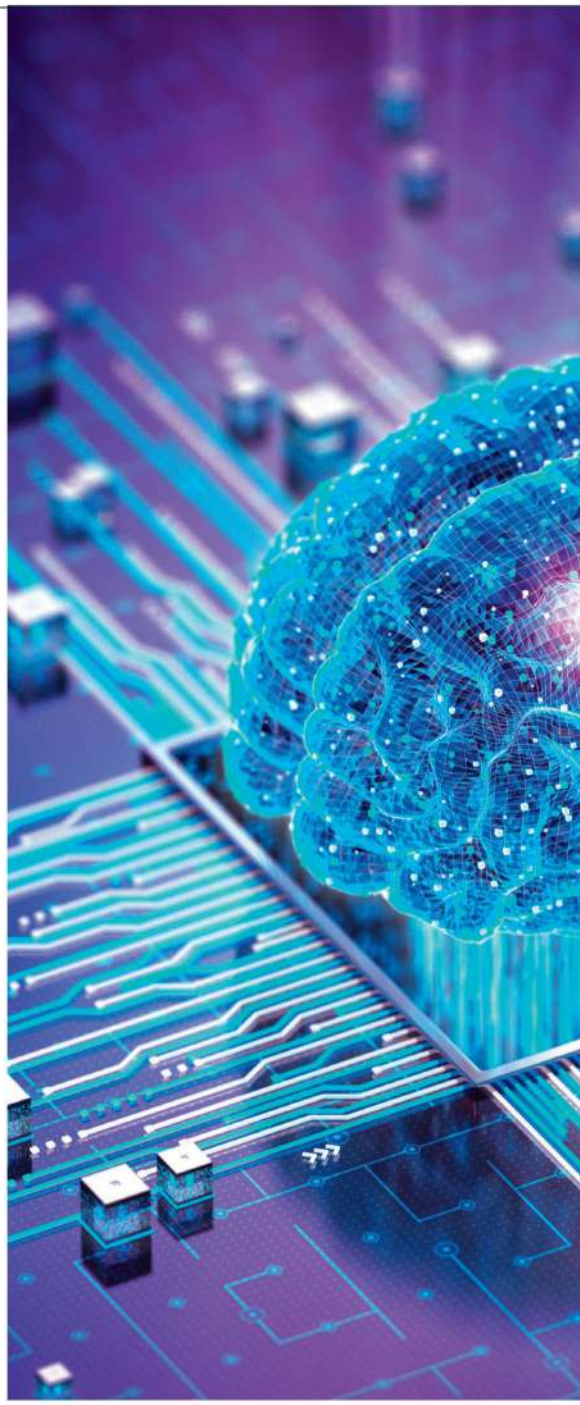
- Easily repairable and replaceable parts
- Five-year warranty
- Eight years of software updates
- Hardy design
- Good display

CONS

- Underpowered
- Dated design
- Better camera phones are available at this price

The AI tools that will streamline your life

Artificial intelligence is having a moment, powering an array of smart tools to improve your workload and everyday existence. Here are our picks of the best AI innovations designed for...



GETTY IMAGES

...Finding answers to everything

When it comes to AI tools, there is no bigger name than ChatGPT. The chatbot developed by OpenAI does a bit of everything. Trying to build a website? It can provide the code. Want to read a fully fledged short story about dinosaurs running local government? No problem – it's written. Need a stand-up comedy routine...? Okay, it doesn't understand comedy whatsoever, but it will try. ChatGPT can best be described as your know-it-all friend who's willing to answer any question you ask... and who's strangely keen to do all of your work for you.

ChatGPT
chat.openai.com

...Creating great presentations

If building the perfect presentation isn't in your wheelhouse – or just something you really don't want to do – Slidesgo is aimed at you. Its AI presentation maker is completely free. Simply specify your topic, preferred style and tone, and set it going. You can then jump in and make any desired changes. Like many AI tools, it can be rather hit and miss, so be prepared to rework your notes on occasions when it has completely misunderstood the level of 'playful' you're after.

Slidesgo
slidesgo.com

...Getting a grip on your email

Working through the deluge of emails arriving each day is a surprisingly mammoth task. Why is a random café emailing about your birthday? When did you sign up for all of these newsletters and promotional emails? No one knows, but they don't stop coming. That's where SaneBox comes in. This AI-powered assistant declutters your emails, pulling the important stuff to the front and organising everything else into neat folders. Over time, it learns what you want to see, prioritising emails from key contacts and hiding the stuff you never open. Reassuringly, nothing is deleted, just moved to virtual back rooms.

SaneBox
sanebox.com

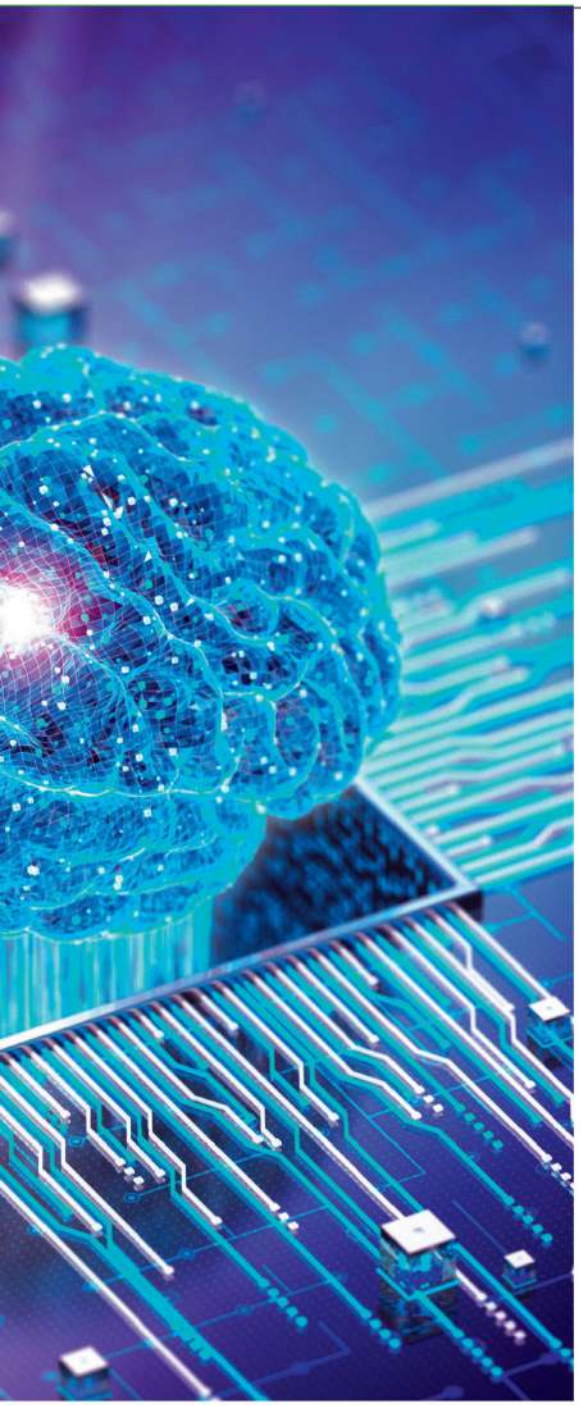
...Sorting your finances

Cleo is an AI-powered app that knows the needs of the younger generation, but hasn't yet worked out quite how to speak to them. It's a treasure trove of budgeting tips and tricks, ranging from payment reminders to budget planners and advice on where to save money. And it's powered by AI systems that learn your spending habits and adapt to them. Sounds great, right? It is... once you get past the weird attempts to be cool. Misunderstood memes, 'Hype mode' and an AI that 'roasts' you – it all adds up to give the impression of a dad who's good with money but desperate to impress his kids.

Cleo
web.meetcleo.com

...Mastering the art of SEO

The techniques involved in effective search engine optimisation (SEO) have evolved enormously. Gone are the days of 'throw it at the wall and see what sticks' efforts. SEO now



"LIKE AN OVERBEARING TEACHER WHO WON'T LEAVE YOUR SIDE, GRAMMARLY WANTS THE BEST FOR YOU"

involves a complicated set of metrics, updates and hard work. Luckily for those just starting out, AI tools can take on a lot of the heavy lifting. SurferSEO is one of the best known, generating SEO-ready content, running website checks and handling most of the nitty-gritty. It can get pretty granular with its adjustments, while always explaining what it is doing.
SurferSEO
surferSEO.com

...Building a website

Constructing your site has never been easier. In fact, with the help of AI, you don't really have to do much work yourself. The coding is taken out of your hands, of course, and now companies such as Wix use AI to handle copy, design, functionality and pretty much every other part of a website. Simply answer a few key questions, provide essential details and voilà! You have a complete website, with the ability to make the small changes required so that it perfectly matches your vision.
Wix ADI
wix.com

....Sourcing a soundtrack

Music generated by AI has come a long way. Not too long ago, the best result you could hope for was a mess of sounds that made experimental jazz seem like Mozart. Now you can choose the genre, speed and even feel of a track – and get something that actually sounds like a real song. There are a few companies in this field, but Soundraw leads the pack. All output is copyright free and the model is trained on music made by the Soundraw team, so there are no concerns over stolen content.
Soundraw
soundraw.io

...Developing the perfect marketing campaign

Jasper is the jack-of-all-trades-master-of-none of the AI world, fully loaded with tools for generating marketing campaigns, writing copy, making images and logos, and even deciding the overall tone of your adverts. By doing so much, Jasper can essentially act as a complete marketing department for your company. However, like most AI tools, it's as eager as it's (sometimes) misguided. Yes, it can create an entire marketing campaign in seconds, but you'll want to run an extra pair of eyes over each part to make it less... well, like it was written by a robot that doesn't understand humans.
Jasper
jasper.AI

...Supercharging your research

When tackling really big projects, research can get messy. It's easy to end up with a morass of browser tabs, vast lists of research papers and a highlighting system that you're sure made sense when you started, but now... Genei aims to tidy up such elements of the research process, summarising background reading, and providing overviews and selecting highlights from long papers. These documents can then be stored in projects and folders that you can search for particular quotes and phrases. You can even ask Genei specific questions about a paper if you're hunting for just one niche idea.
Genei
genei.io

...Perfecting writing

We all make mistakes in our work documents, emails, newsletters and just about any other piece of writing. Like an overbearing teacher who won't leave your side, Grammarly just wants the best for you. It identifies not only grammatical and punctuation errors, but also suggests ways to sound more articulate. This AI-powered tool might occasionally misunderstand your tone, perhaps making you sound oddly passive-aggressive to a colleague or somewhat stuffy in a fun piece of writing, but for the most part it'll just save you from spelling faux pas.
Grammarly
grammarly.com

Ideas we like...

Our pick of the month's smartest tech

...A pop-up desk for WFH

My laptop sits on a throne of cardboard boxes. This serves two purposes: it cuts out neck-ache and it prevents people on video calls from being subjected to the sight of my dangling double chin. Realising just how many of us endure such a makeshift working-from-home setup, Logitech has come up with a rather cute solution. The Casa Pop-Up Desk is disguised as a coffee-table book by night, but by day it folds out into a laptop stand. A wireless keyboard and trackpad are hidden inside, so you can create your own comfortable workstation when you need it.

Logitech Casa Pop-up Desk
logitech.com, £179.99

...A truly advanced instant camera

"Made for those who embrace chaos, beauty in the everyday and the tactile pursuit of craft," is how the Polaroid website introduces its latest camera. Hyperbole aside, the new I-2 seems less about embracing chaos and more about a willingness to drop almost £600 on the best instant film kit possible. The first analogue instant camera with built-in manual controls, the I-2 uses Polaroid's sharpest lens yet, and offers six modes, adjustable aperture and shutter speed, and a wide range of features not seen on any other similar camera.

Polaroid I-2
polaroid.com, £599.99

...A solar-powered speaker

Urbanista hates chargers with a burning passion. Okay, that's an exaggeration, but the company is definitely set on the idea that there are better ways to keep your devices going. Yet another Urbanista product powered by the Sun, the Malibu is a portable speaker that charges using Powerfoyle solar-cell technology. Along with essentially endless battery life, it's fully water-, sand-, dust- and dirtproof. It's unlikely to be a market-leading speaker sound-wise, but, as a take-anywhere device, the Malibu is designed to withstand being dropped, chucked in a bag and dragged along to all kinds of outdoor events.

Urbanista Malibu
urbanista.com, £TBC

...A Sony handheld gaming device

It's been 10 years since the previous handheld PlayStation console, the Vita – and what a flop *that* was. Now Sony has brushed itself off and is ready to try again with the PlayStation Portal. This handheld device borrows from the market-leading Nintendo Switch, with a left and right controller joined by a screen in the middle. It's able to play any game you have installed on your PS5 console and costs £199. So what's the catch? It needs a strong Wi-Fi connection, so it's less for taking out and about, more for playing around your home or on holiday.

PlayStation Portal
playstation.com, £199.99

...Apple's gaming iPhone

Yes, yes, we know: Apple has made yet another smartphone – big whoop. And though this model is, for the most part, near identical to what has come before, some new features reflect the kind of innovation that made earlier iterations so exciting – not least eco-friendly design and considerable improvements to the camera. Arguably most important is another step up in processing power combined with ray-tracing technology that could enable iPhones to run high-end games such as *Resident Evil* and *Assassin's Creed*. That's still tbc, but Apple would win us over if its new iPhones can replace consoles.

iPhone 15
Apple.com,
from £799

IDEAS WE DON'T LIKE...

...THE EXTRAVAGANT HOME BAR

Sure, you could learn to make your favourite cocktails. Or you could invest in a cocktail-making machine that looks as if it's been swiped from the set of *Blade Runner*. Barsys 360 is a futuristic ring that will set you back £395. Select your favourite spirits and mixers, and the 360 will suggest a list of possible cocktails that it can make, and then pour the ones you want, learning over time just how you like your drinks. It's a good idea in theory – less so when you realise that's all it does, leaving you with a selection of basic cocktails and a deep hole in your wallet.

Barsys 360
thebarsys.com, £395

...A CREEPY ROBOT IN THE WORKPLACE

If the super-powered androids of *I, Robot* had a dopey brother, it would be the new Apptronik Apollo. Designed to look mostly human, it has a head, arms, legs, a body and the soulless stare that can come only from an entire lifetime spent doing menial tasks. And in a way, that's apt: the Apollo is designed to be a new kind of factory worker, able to carry heavy boxes and receive commands for a full day's toil, even making small talk – or the occasional 'hello', at least. But don't worry: it won't go on sale until 2025, so there's still time to run.

Apollo General Purpose Humanoid Robot
apptronik.com,
£TBC

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NEW YORK TIMES/REDUX/EYEVINE

RESCUE BOTS

BURNING BUILDINGS, COLLAPSED TUNNELS, SINKING SHIPS... WHEREVER YOU MIGHT FIND YOURSELF TRAPPED AND IN DANGER, THERE'S A ROBOT DESIGNED TO COME TO YOUR RESCUE

by HAYLEY BENNETT

SEND IN THE 'DOGS'

SPOT, BOSTON DYNAMICS

Over 1,000 of these yellow robots, dubbed Spot, are already patrolling factories and power plants. And now the New York City Fire Department is starting to use the dog-like devices for search-and-rescue missions. In April 2023, it was reported that a Spot had been sent in to survey the remains of a collapsed car park that was considered too unstable for fire crews to enter.

Developed by Boston Dynamics, a spin-off from the Massachusetts Institute of Technology (MIT), Spot can access places people can't get to, send back video footage, identify hazards, carry up to 14kg (30lbs) and, when fitted with an add-on 'arm', open doors and flip switches.

Not everyone has been convinced of Spot's suitability for work with the emergency services, however. In 2020, the New York City Police Department started testing Spot, but cancelled its arrangement with Boston Dynamics following a public backlash.

GETTY IMAGES, CARNEGIE MELLON UNIVERSITY, GEORGIA INSTITUTE OF TECHNOLOGY

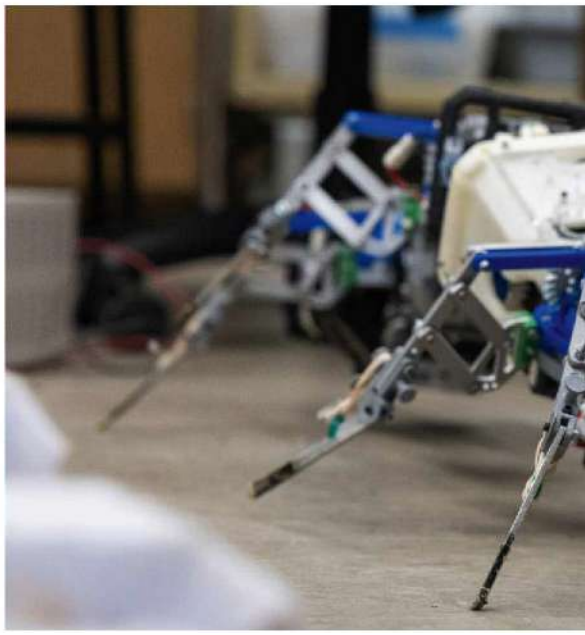
TRAIL BLAZERS

FIRE FIGHTING ROBOT, ANSHAN HENGYE SPECIAL VEHICLE MANUFACTURING CO

Here, at the Bajiao Fire Rescue Station, in Yantai, northeast China, a firefighter tests out a fire-fighting robot. For a few years now the Chinese government has been promoting the technology, which allows human firefighters to remain safely outside the danger zone of a blaze while controlling robot extinguishers.

Back in 2020, the city of Tongliao, in northern China, unveiled its brigade of firefighting machines. Known as 'Blade Formation', the 10-strong unit includes robots, drones and a transport unit. Elsewhere, ground-based robot firefighters are employed to extinguish fires at chemical plants and in subways.

One major advantage of this approach is fire resistance – robots can work at temperatures of 1,000°C (1,800°F) for over 30mins. They can also use sensors to detect heat sources, tricky terrain and combustible gases. One day, they could even replace home fire alarms and fire extinguishers. In 2022, Chinese researchers published a paper describing small, lightweight "home-use fire-fighting robots".



GOING UNDERGROUND

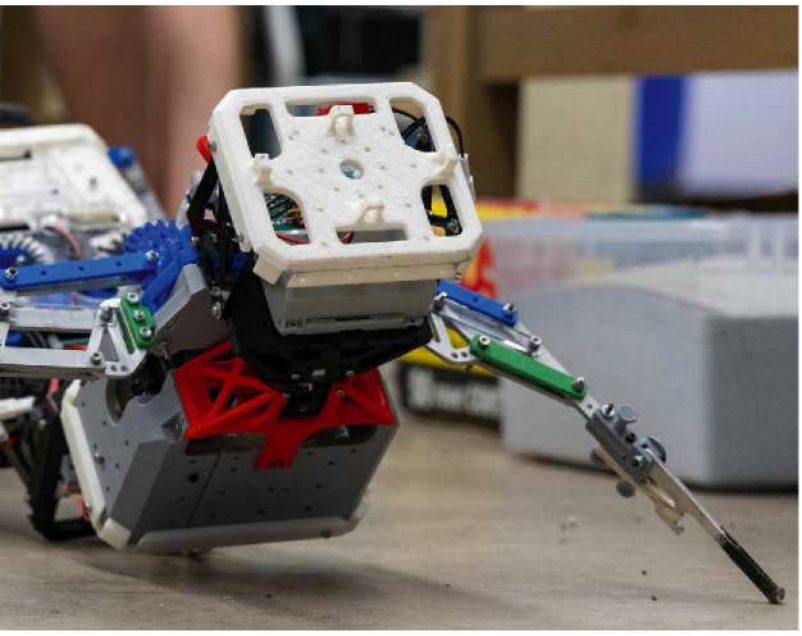
TEAM EXPLORER, CARNEGIE MELLON UNIVERSITY & OREGON STATE UNIVERSITY

Searching for people trapped in dark underground tunnel and cavern complexes isn't most people's idea of fun, but in 2017 the US Defence Advanced Research Projects Agency (DARPA) turned it into a game. The survivors may not have been real, but the giant subterranean spaces were.

Players were tasked with developing and using autonomous robotic systems to seek out mannequins and other objects in order to score points. DARPA devised the competition to drive innovation in autonomous subterranean mapping and navigation, which could benefit rescue workers working after mine collapses and in cave rescue operations.

Following several rounds of competition, the finals of the 'SubT' challenge took place in 2021 at the Louisville Mega Cavern in Kentucky. Pictured here is a ground robot and drone entered by Team Explorer, from Carnegie Mellon University and Oregon State University, which made it through to the finals.

Although Team Explorer didn't scoop the $2 million (about £1.6m) top prize, its robots did map more of the underground course than any other team. And the success of its aerial tech inspired the establishment of Canary Aero, a company that makes drones for mapping mines and inspecting infrastructure.



LET YOUR LEGS DO THE WORK

MULTILEGGED MATTER TRANSPORT, GEORGIA INSTITUTE OF TECHNOLOGY

In an article published in *Science* in 2023, researchers at the Georgia Institute of Technology explained that "serially connected legged robots leads to reliable transport on [tricky] terrain without requiring sensing and control". Or to put it another way: a robot based on a centipede doesn't need eyes – a surprising fact that's reflected in nature, for some species of centipedes, at least. And although the centipede-like robot pictured here doesn't quite have the same number of limbs as the arthropod that inspired its creators, models sporting up to 18 legs have been tested.

According to the paper's authors, such sensor-free tech can reduce costs and may have an advantage in rapidly changing environments where there is no time for a controller to respond to information detected by the robot about its surroundings.

↓→

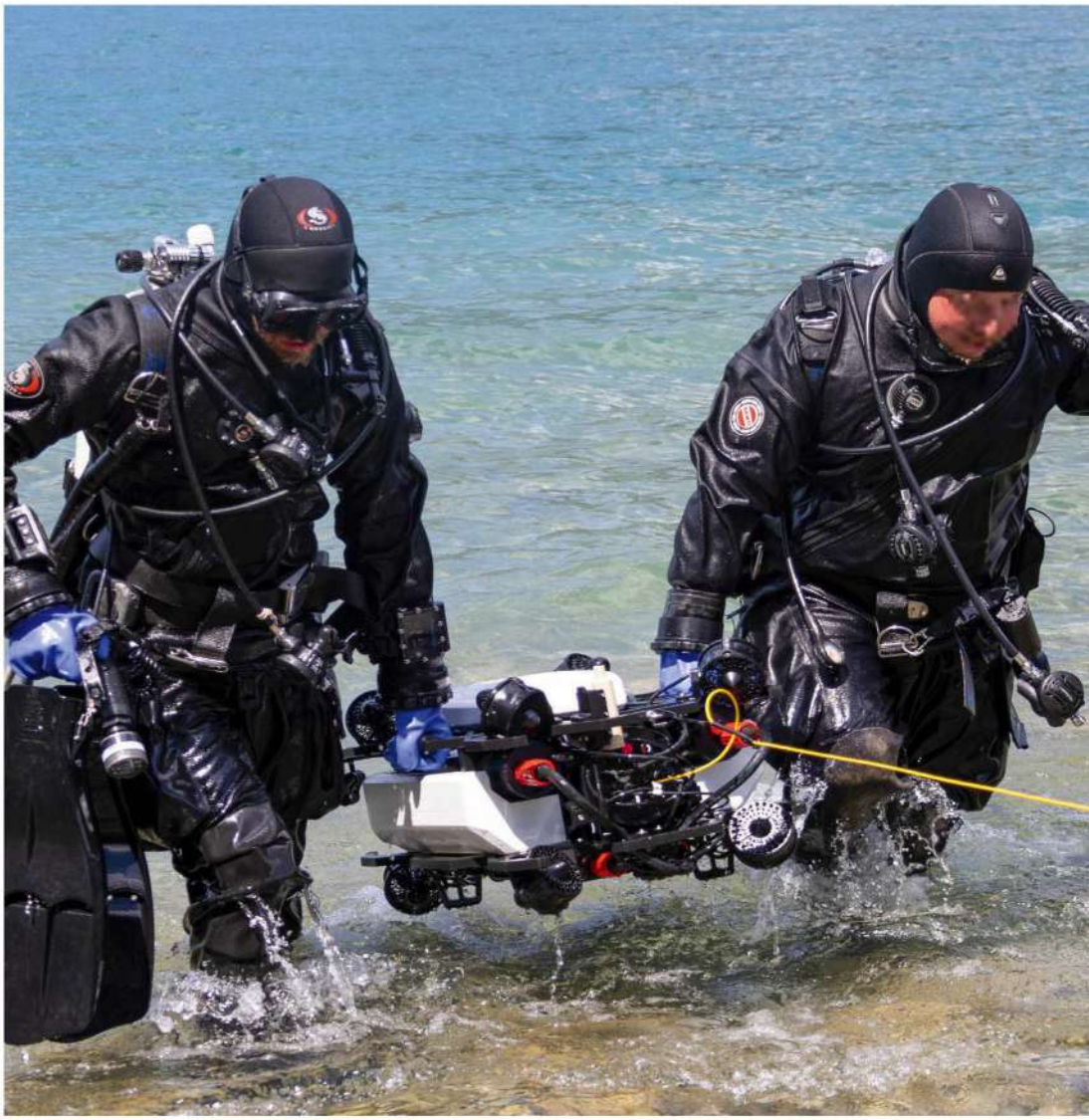
MINE SWEEPER

PROTEUS, TETHYS ROBOTICS

Divers from the Swiss armed forces return to shore with their Proteus robot following a successful test. Developed for search, recovery, inspection and surveillance through a collaboration between Tethys Robotics and the Swiss Drone and Robotics Centre of armasuisse Science + Technology, the Proteus prototype was given to explosives disposal experts in 2022 to test its ability to detect metallic ammunition.

According to Tethys CEO Jonas Wüst, the murky and turbulent environment of the ocean poses the biggest challenge for this robot. "In order to work under these conditions, innovative software solutions have been developed that enable the robot to perceive the environment and act accordingly," he says.

Currently, the robot performs its tasks at the end of a tether, using AI-powered perception to position itself at depths beneath 300m (985ft). However, Tethys is developing fully automated and untethered robots that, Wüst notes, need to be advanced enough to match the expertise of human divers in the unpredictable conditions found in the deep ocean.



TETHYS ROBOTICS X2, CARNEGIE MELLON UNIVERSITY X2

↓→

SNAKE EYES

MODULAR SNAKE ROBOT, BIOROBOTICS LAB

When an earthquake hit Mexico City in 2017, the Mexican Red Cross asked researchers from the Biorobotics Lab at Carnegie Mellon University to deploy their snake robot to search for survivors amid the rubble. Although the serpentine bot didn't find any people, it was able to demonstrate the utility of robots modelled on snakes by providing a live feed from within the wreckage to help rescue teams.

Since then, the Biorobotics Lab has updated the robot's software, made its user interface more intuitive and developed a swimming robot with a similar design. Prof Howie Choset, co-director of the lab, explains that his team bases its robots on snakes because they can slip through tiny spaces and reach locations that people and other machines can't. "This is important in search and rescue when time isn't on your side and you want to locate victims as quickly as possible and without disturbing what is likely a fragile environment," he says.

INSPECTOR GADGET

ANYMAL, ANYBOTICS

ANYmal is a four-legged robot devised to carry out autonomous inspections at industrial facilities. It's the successor of several generations of legged robots from the Swiss Federal Institute of Technology in Zürich and its spin-off company ANYbotics.

Chemical producer BASF has tested the most up-to-date ANYmal at its plant in Ludwigshafen, Germany, where it was used to check the state of equipment while navigating its way around the site. ANYmals are also designed for use in power and renewable energy plants or oil and gas refineries, where they can collect data in places that might be dangerous for people to reach.

These robots have the potential to be adapted for search-and-rescue missions, even though those applications pose extra challenges, as ANYbotics' senior director of marketing communications, Tilman Eberle, acknowledges: "These uses require additional sensors and navigation skills that are in development." But he also goes on to say that "ANYmal can already master extremely tough terrain and unstructured environments in a research context."

LIGHTNING SWARM

LIGHTNING BUG ROBOT, MIT

Inspired by fireflies, these 'lightning bug' robots are almost as small as their real-life counterparts, and can glow in various colours. The soft, muscle-mimicking materials that MIT scientists used to control the robots' tiny wings can contract 400 times a second. This produces the lift required to enable the bot to fly, but also generates a strong electric field that activates luminescent particles embedded in the 'muscles', making them glow.

The scientists designed them with search-and-rescue operations in mind – they intend the bots to use their lights to signal to and track each other: a low-power communication strategy for a lightweight robot. "We envision sending hundreds or more of these tiny robots into a disaster site, and having them collectively search for survivors," says MIT robotics engineer Prof Kevin Chen. "Once a survivor is found, they'll then pass the information out to the operators."

The bots are currently tethered on tiny wires, but the researchers are working with other MIT teams to make miniature batteries and circuits so that the robots can fly untethered.

ANYBOTICS, ROBOTICAN X2, MIT

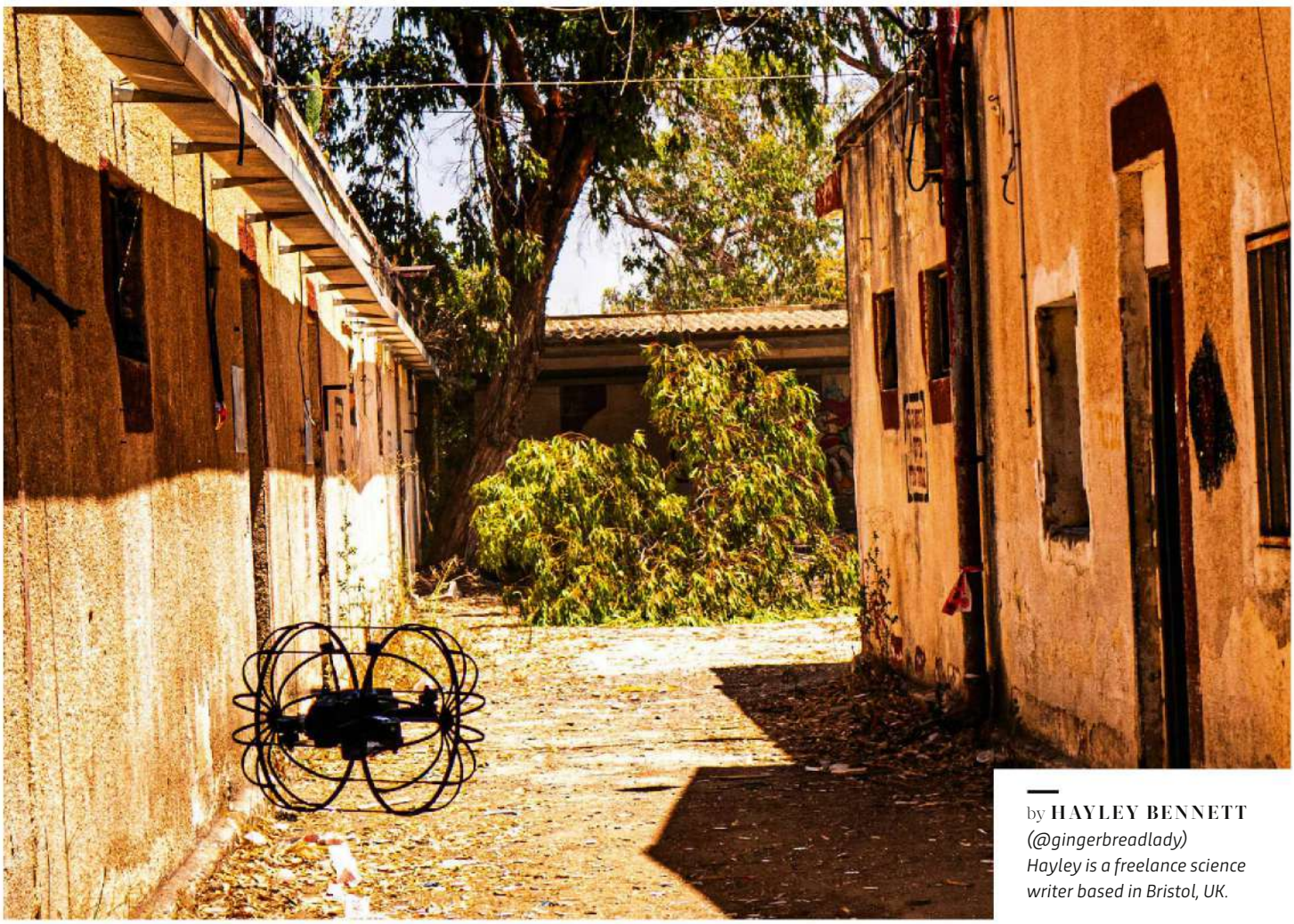
CAGED BIRD

ROOSTER, ROBOTICAN

The Rooster is a slightly incongruous name for this reconnaissance robot from Israeli company Robotican, since, unlike its namesake, it is capable of flight. It might look like a drone in a birdcage but, thanks to its clever design, it's as capable on the ground as it is in the air. It can roll across surfaces or fly around to navigate almost any type of disaster site, manoeuvring through narrow passages and windows, or over obstacles and up or down staircases.

According to Robotican, the cage-like structure that forms the Rooster's wheel is protective but also flexible, enabling it to handle different terrains.

Designed to assist in search operations, the robot uses cameras and sensors to scan a space, so that rescuers don't need to enter dangerous areas needlessly. Rooster can also communicate with search teams and other robots via a mesh radio link – the same kind of communications system used by the US military for field operations. In a 2023 test exercise, Spanish armed forces used a Rooster to scan an enemy building. **SF**

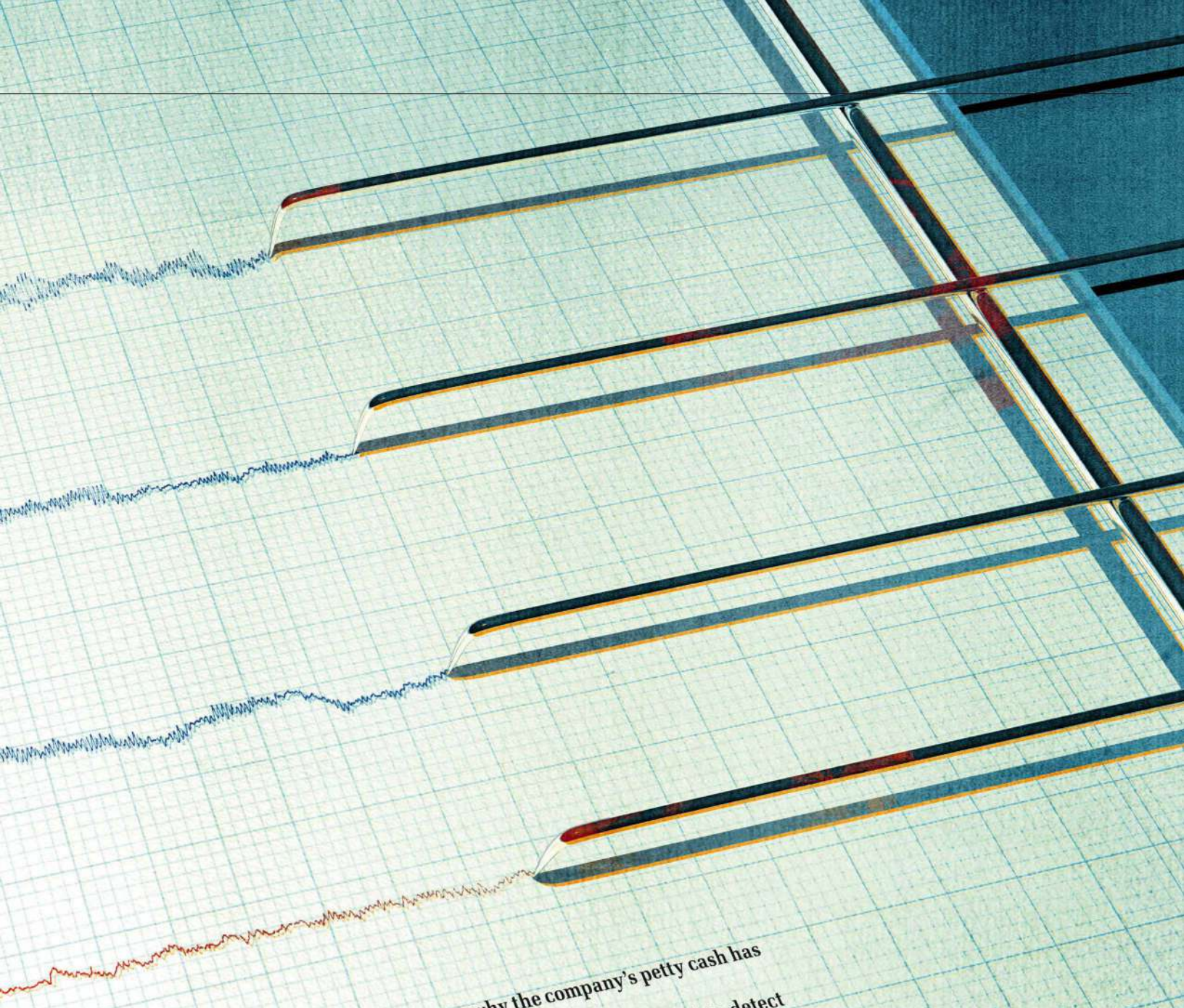


by **HAYLEY BENNETT**
(@gingerbreadlady)
Hayley is a freelance science writer based in Bristol, UK.

THE NEW SCIENCE OF SPOTTING A LIAR

WORDS: DR JULIA SHAW

We've been getting lie detection wrong for 100 years. Now scientists are trying to fix the problem



We naturally detect lies all the time. It could be a dip in our partner's voice alerting us to the fact that they're concealing their emotions; a child's eyes drifting back to the drawer containing a present they weren't supposed to open; or an implausible story told by a colleague trying to explain why the company's petty cash has gone missing.

Yet we also often fail to detect lies. Why? Researchers have been trying to answer this question for over a century and the liars are still slipping through our fingers. But the latest research may help shine a light on where we've been going wrong. →

ILLUSTRATION: ANDY POTTS

→ A notable recent study was conducted by Associate Prof Timothy Luke and colleagues at the University of Gothenburg. They looked at research published over the past five years by 50 international experts on lie detection to analyse how they go about telling when someone is lying.

But first they had to decide on exactly what a lie is. We might use the word 'lie' when referring to someone saying an outfit you're not sure about looks good, or a partner you think is trying to hide an affair, or a murderer who claims to be innocent. But are these comparable? Surely some lies have greater significance than others? Luke prefers to separate 'white' lies from what he calls deception.

"The construct of deception is more complicated than a lot of people think," he says. "There are many kinds of psychological processes that can underlie it. We're not talking about the same thing. Even superficial things, such as the length and type of communication, matter."

Whether you're texting your lie or telling it straight to someone's face, the core of deception is an intentional attempt to mislead another person, Luke says. But deciding what constitutes a lie is one thing; detecting it is quite another. Are there really any cues that reliably betray deception in others?

"SEVENTY-TWO PER CENT OF EXPERTS AGREED THAT LIARS PROVIDE FEWER DETAILS THAN PEOPLE WHO TELL THE TRUTH"

THE EYES DON'T HAVE IT

One commonly held belief is that liars are reluctant to meet another person's gaze. And yet, in the Gothenburg study, 82 per cent of experts agreed that liars are no more likely to avoid eye contact or look away than truth tellers.

"The empirical work on deception detection is massive," says Pär-Anders Granhag, a professor of psychology at the University of Gothenburg and one of the study's co-authors. "But the only single issue that a large majority of the experts agree upon is that gaze aversion is not a diagnostic cue for deception."

Similarly, 70 per cent of the experts agreed that liars don't seem more nervous than truth tellers. This might come as a surprise, as nervousness and gaze aversion are two of the four key behaviours supposedly displayed by liars. The other traditional indicators are that a liar will continually shift posture or touch themselves more often, and will give an account that's less plausible, logical or consistent than if they were telling the truth.

These beliefs also stand on shaky empirical ground. The researchers found that links between deception and fidgeting (body movement), the lengths of time it took for subjects to answer questions (response latency), and whether their accounts were consistent, made sense or were expressed easily (fluency) were not clear-cut. Some experts said that liars did these things

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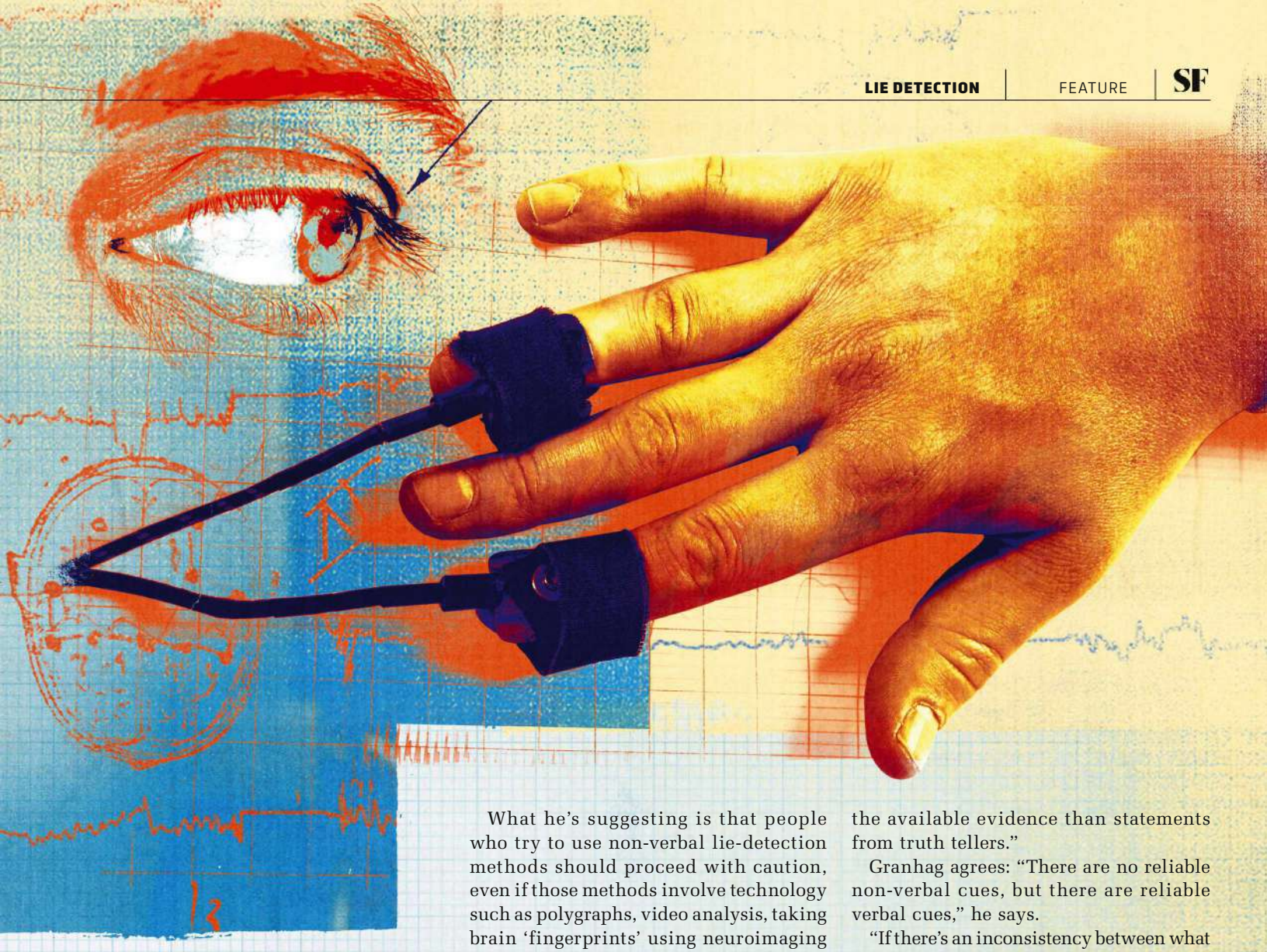


ABOVE
Existing methods of lie detection, such as a person's wayward glance (or a perceived lack of – or over emphasis on – eye contact) are simply not reliable general indicators of lying. The same goes for methods that claim to rely on technology, such as polygraph testing

more, some that they did them less, and others that there was no difference.

WORDS MATTER

Prof Aldert Vrij, an expert in the psychology of deception at the University of Portsmouth, wasn't involved with the Gothenburg survey, but says that the most prevalent misconception about deception is "the idea that non-verbal lie detection works."

What he's suggesting is that people who try to use non-verbal lie-detection methods should proceed with caution, even if those methods involve technology such as polygraphs, video analysis, taking brain 'fingerprints' using neuroimaging machines, or looking for changes in vocal pitch – all of which are controversial areas of deception-detection research.

So are there *any* effective methods for spotting a liar? According to Luke, one cue is promising: a lack of detail. Some 72 per cent of experts agreed that liars provide fewer details than truth tellers.

Vrij agrees, saying that instead of examining how people behave, we should examine what they say. He says that there are several verbal indicators, including the number of details and the 'complications' that appear in a subject's statement.

Complications are things that go wrong or are unexpected. They add clusters of details that make a story more convoluted – for example, saying that you initially didn't see someone you were due to meet because they were waiting at a different entrance from the one you expected them at.

Vrij also points out another tell.

"Statement-evidence inconsistency is another cue," he says. "A liars' statements are less consistent with the available evidence than statements from truth tellers."

Granhag agrees: "There are no reliable non-verbal cues, but there are reliable verbal cues," he says.

"If there's an inconsistency between what a person tells you and the facts that you hold, there is a high likelihood that the person is trying to deceive you," he adds.

For example, if you have footage of someone committing a crime, but that person says that they didn't do it, it's quite likely that they are lying to you. This seems so obvious that it almost doesn't need to be said. However, the benefit of making this explicit is that it steers an investigator away from guessing whether a potential culprit is lying based on how they're behaving, and forces them to look at the available facts instead.

CHALLENGE DISCREPANCIES

Turning this into advice for those who need to separate lies from truth, including detectives, Luke and Granhag have proposed a 'Shift-of-Strategy' approach to gather information that suspects are intentionally concealing. It involves drip-feeding evidence to a suspected liar to challenge discrepancies in their story without directly accusing them of lying. →

→In practice, this involves asking someone what happened, then presenting them with evidence that contradicts their statement, and seeing how they try to accommodate it.

"If a person changes their story when you present parts of the background information that you hold, you're on your way to catching a lie," says Granhag.

This method isn't perfect. Investigators who use it need to be conscious that what seems like a lie can sometimes be down to a simple error of memory, especially if the suspect is asked about an event that happened long ago. Differentiating between an intentional fabrication and an unintentional one (or a false memory) is often very difficult.

"WHAT SEEMS LIKE A LIE CAN SOMETIMES BE DOWN TO A SIMPLE ERROR OF MEMORY"

Despite the problems associated with purported behavioural tells, such as gaze aversion, Vrij says that many practitioners are reluctant to swap those for more useful cues based on what a suspect is saying. Old myths and methods die slowly.

"Most annoying is the assumption that comes from TV shows... that lead the general public [and] professionals, to think they can catch an individual liar,"

GETTY IMAGES, ALAMY. IMAGE MANIPULATION: ANDY POTTS

says Prof Amina Memon of the University of London, a leading researcher on lie detection and investigative interviewing, and another of the Gothenburg study's co-authors.

Police following a hunch about a suspect based on the stereotypical profile of a liar may use coercive tactics that cause innocent people to confess to crimes they didn't commit. Because of this, Memon advocates for a neutral, fact-finding approach to interviewing, rather than trying to guess whether someone is lying.

But there's a bigger issue lurking behind all of this. Perhaps the reason why we haven't found universal cues to deception is because they simply don't exist.

For the past century, researchers have almost exclusively taken what's known as a nomothetic approach. This means that they're looking for the 'laws' of deception – cues that are exhibited by everyone. But maybe this kind of one-size-fits-all approach hasn't worked simply because everyone lies differently.

A poker player applies this logic when they look for another player's 'tells' – behaviours that indicate whether that person is bluffing. Tells are unique to individuals, so one person might scratch their nose when they have a bad hand, another might cough more, while yet another looks more calm than usual. If you throw these three people into a research setting, a nomothetic approach won't get you far. These differences will simply look like noise.

UNIQUE SIGNS

If we want to understand the cues, researchers need to adopt an 'ideographic' approach and focus on what makes each individual unique, argues Luke. This would involve creating a personal profile of how each person lies about the same kinds of things, and in similar settings.

"Testing the same person under varying conditions (so-called 'repeated measures' experimental design) is the way to go," says Memon. →

→One example of this approach was published in a 2022 paper by Dr Sophie van der Zee and co-authors, who developed the first deception model specifically tailored to an individual.

Using a fact-checked database of tweets by Donald Trump while he was president, they found that the language he used when he lied was systematically different from his truthful tweets. Once they made a personalised profile, the scientists could predict whether his tweets were untrue with an accuracy of 74 per cent.

This kind of personalised deception-detection model can work for those who already have a large online presence in which they lie a lot. Artificial intelligence can help collate and examine these existing data. But what about people who are less present online, or who don't lie in posts?

Some things you can fact-check, but most everyday posts and messages are so personal that it's hard to even identify them as lies, so even AI models may struggle.

"There's no guarantee that a machine-learning model is going to actually work in ... situations where you don't know the right answer" Luke says.

Exactly how researchers are going to overcome logistical barriers remains to be seen, but it seems clear that a shift in the science of lie detection is underway. It's time to move away from what Luke calls "crude averages". "People are a little too fascinated by having a cool trick to catch someone in a lie," he says.

The crux is that researchers studying deception have repeatedly found that evidence from controlled environments shows most people are bad at detecting lies. The liars can evade detection partly because they also know the stereotypes and play into them.

Our confirmation bias can also make us overconfident: we disproportionately remember the times when we caught liars and don't realise all the other times when we didn't.

"THOUGH BEHAVIOURAL CUES FOR DECEPTION MAY EXIST, THEY ARE LIKELY TO BE HIGHLY PERSONAL"

In instances when we succeed, too, Luke isn't convinced that the cues we think we employed really are the keys we used to unlock the truth.

"Think about the last time that you caught someone in a lie. How did you know?" he asks. "It's probably not because they looked up and to the left. You probably had some evidence: a receipt, a text message, a witness. These are the ways people tend to actually tell whether someone is providing the truth."

Even when you don't have concrete external evidence, you may be able to assess situational factors.

"In the real world, you often have some understanding of why someone would be motivated to lie," says Luke.

The reason you're better able to guess when someone you know is lying from subtle cues, such as glances, is because

GETTY IMAGES, ALAMY IMAGE MANIPULATION: ANDY POTTS

you know them. In these situations, it's best to read the situation more than the person, says Luke, and try to figure out their motivations.

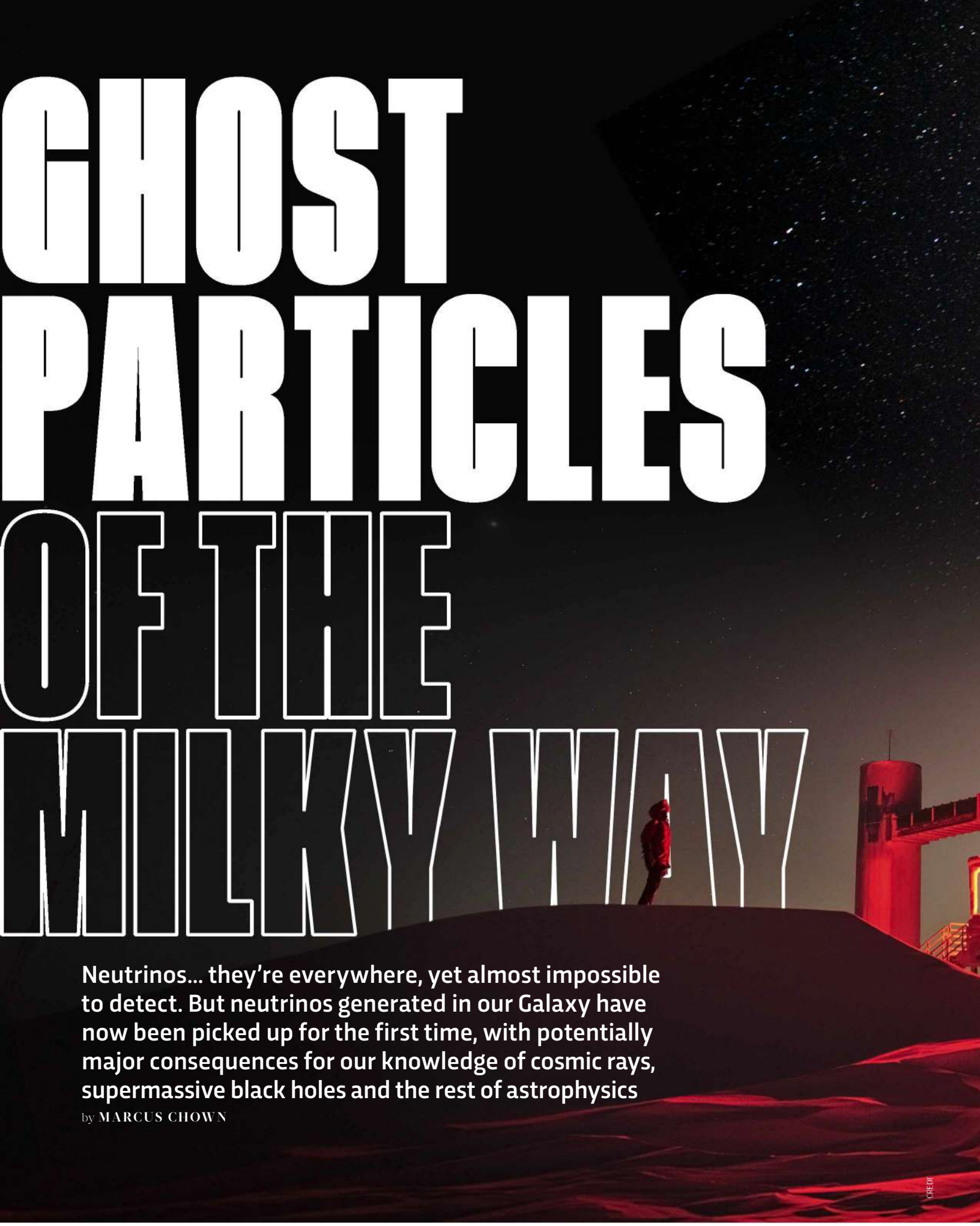
The take-home message is that, though behavioural cues for deception may exist, they're likely to be highly personal.

"It's better to trust your own detective work and check what people say against evidence," says Luke.

Stereotypical cues are not going to cut it – in fact, they might actually make you worse at catching a liar. And if you can't find any evidence? Luke's advice is simple: "proceed with caution." **SF**

by **DR JULIA SHAW** *(@drjuliashaw)*
Julia is a criminal psychologist and author based at University College London. She also co-presents the Bad People *podcast, available on BBC Sounds*

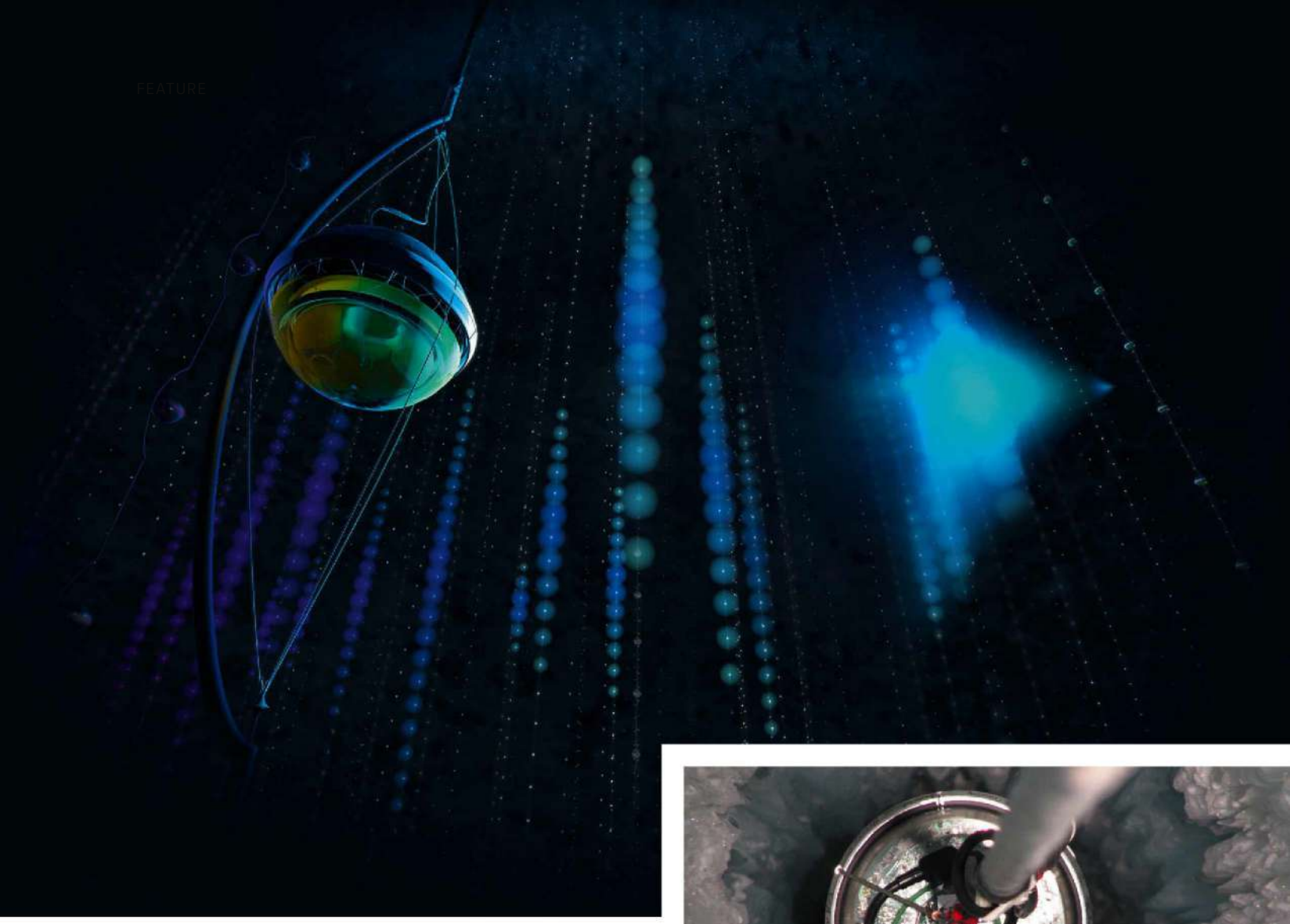
GHOST PARTICLES OF THE MILKY WAY

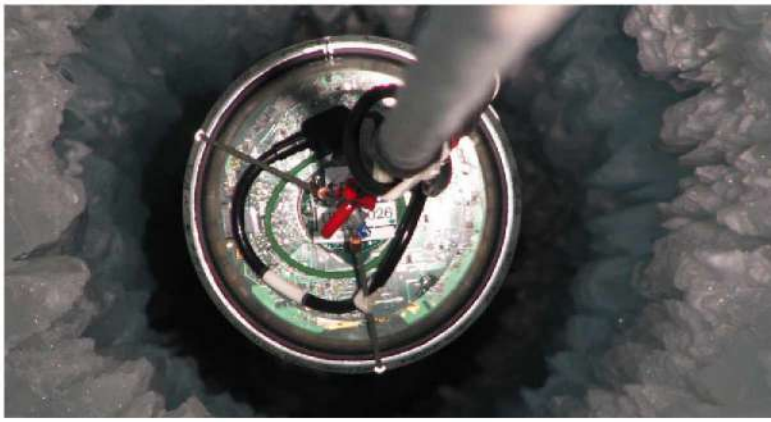


Neutrinos... they're everywhere, yet almost impossible to detect. But neutrinos generated in our Galaxy have now been picked up for the first time, with potentially major consequences for our knowledge of cosmic rays, supermassive black holes and the rest of astrophysics

by MARCUS CHOWN

CREDIT





How do you detect the undetectable? That's the challenge scientists have faced since the most ghostly, elusive subatomic particle, the neutrino, was posited nearly a century ago.

Yet now they've been detected. In June, neutrinos generated from elsewhere in the Milky Way were spotted. It's the first time we've seen anything but photons of light from our Galaxy. The particles are tiny, but the discovery is huge.

"We're truly at the dawn of neutrino astronomy," says Steve Sclafani of the University of Maryland, one of the scientists involved in the project.

It's fair to say neutrinos are strange. They're the second-most abundant subatomic particles in the Universe, after photons, but they're extraordinarily elusive. So rarely are they stopped by anything in their path that, when Austrian physicist Wolfgang Pauli proposed their existence in 1930, he apologised to his fellow physicists.

"I have done a terrible thing," he said. "I have predicted a particle that can never be detected."

To get an idea of just how elusive they are, hold up your thumb. Every second, about 100 billion neutrinos from the core of the Sun stream through your thumbnail, and almost none of them are stopped by it.

Pauli bet a case of champagne that nobody would ever detect a neutrino. But towards the end of his life, he lost that wager.

On 14 June 1956, Frederick Reines and Clyde Cowan announced that they'd picked up neutrinos streaming out of a nuclear reactor at the Savannah River Plant in South Carolina. Their trick was to create a target that

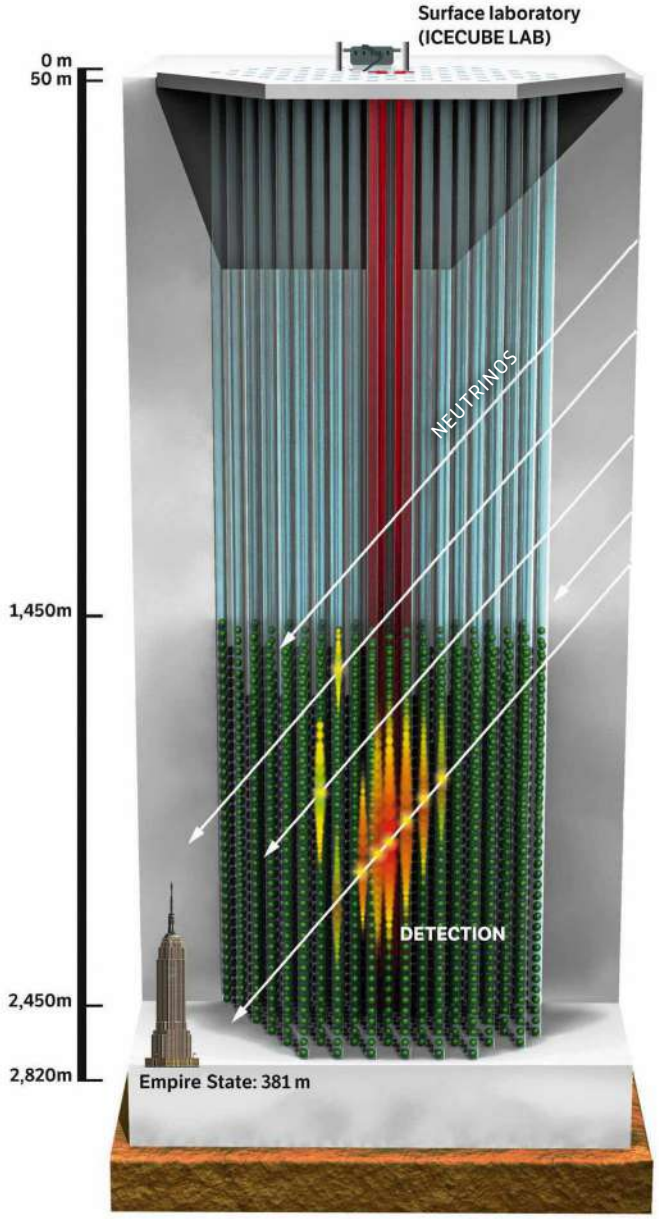
"NEUTRINOS ARE THE SECOND-MOST ABUNDANT SUBATOMIC PARTICLES"

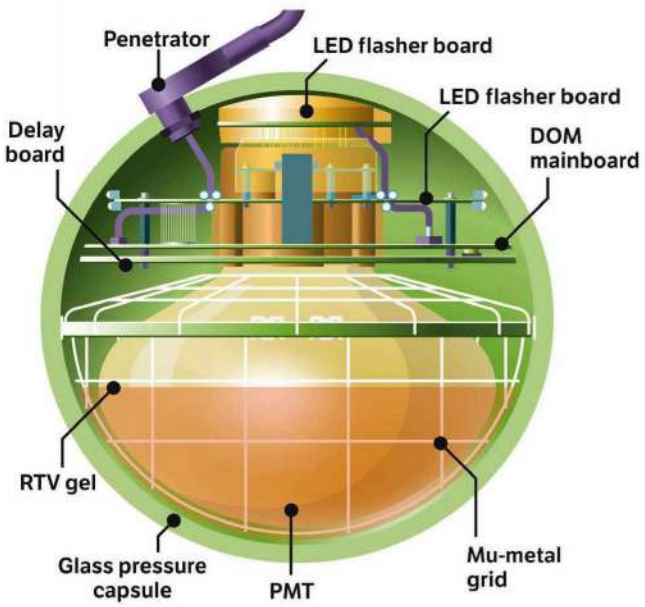
TOP Neutrinos hitting the IceCube detector produce Cherenkov radiation, leaving trails of blue light

ABOVE A Digital Optical Module (DOM) is lowered into the ice

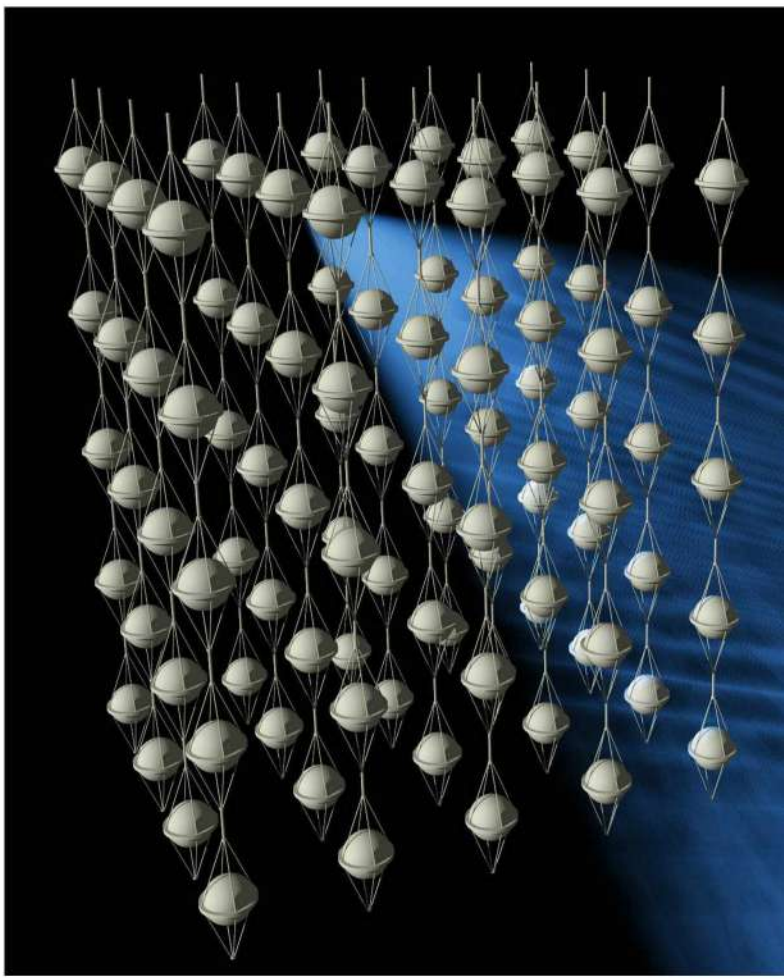
RIGHT A cutaway diagram showing the size of the IceCube detector (top) and a DOM (bottom)

FAR RIGHT The detector comprises more than 5,000 DOMs on 86 strings





NICOLLE R FULLER/NSF/ICECUBE, MARK KRASBERG/ICECUBE/NSF, SCIENCE PHOTO LIBRARY X2



contained a vast number of atoms, thus boosting the chance that at least one of the elusive neutrinos would be stopped.

TINY PARTICLES, GIGANTIC TARGET

Creating an unmissable target is same strategy used by the physicists who recently detected neutrinos from out in the Milky Way. Their target was gigantic: a 1km^3 block of ice near the Amundsen-Scott South Pole Station in Antarctica.

The detector, aptly named the IceCube Neutrino Observatory, is operated by a group of around 300 scientists from 58 institutions, led by the University of Wisconsin-Madison. It looks for neutrinos with energies thousands of times greater than anything that can be created in the proton-proton collisions at the Large Hadron Collider near Geneva.

Occasionally, a high-energy neutrino passes through the IceCube detector and shatters an atomic nucleus in a water molecule. This results in a cascade of subatomic shrapnel, with some of the particles travelling through the ice faster than the speed of light. These create a shock wave (the light equivalent of a sonic boom), which appears as a ghostly blue glow, known as Cherenkov radiation (named after the Nobel prize-winning physicist Pavel Cherenkov).

The Cherenkov radiation is picked up by thousands of photomultipliers in digital optical modules, extremely sensitive light detectors spaced out along strings lowered through holes drilled into the ice. Because the subatomic shrapnel is emitted in roughly the same direction as the impacting neutrino, it's possible →

"ICECUBE IS HIT BY SEVERAL THOUSAND LIGHT-GENERATING MUONS EVERY SECOND"

→ to deduce the neutrino's trajectory based on when the shrapnel's Cherenkov radiation arrives at different photomultipliers.

According to IceCube scientist Mirco Hünnefeld of TU Dortmund, a university in Germany, the team faced a particularly testing problem detecting neutrinos from the Milky Way. The neutrino signal they sought is mimicked by muons, subatomic particles created when cosmic rays – high-energy atomic nuclei from space – smash into atoms at the top of the atmosphere.

"If IceCube looked through Earth, these could be screened out by the mass of the planet," says Hünnefeld. " But the Milky Way is in the southern sky, directly above IceCube, so no such screening was possible. It means that IceCube is hit by several thousand light-generating muons every second."

Considerable ingenuity was required to isolate neutrinos generated in the Milky Way from this confusing background noise. Knowing that muons would predominantly interact in the surface layers of the detector, creating tracks that extend inward from the periphery, the physicists looked instead for localised

ABOVE The first 'map' of neutrinos in the Milky Way is a composite image combining visual light with detected neutrinos (in blue)

BELOW Physicist Enrico Fermi, who proposed a mechanism for the acceleration of super-energetic cosmic rays, which may be related to neutrino emissions

ICECUBE COLLABORATION/NSF/LILY LE/SHAWN JOHNSON/ESO/S BRUNIER, MARISSA HUNNEFELD, HUBBLE SPACE TELESCOPE, GETTY IMAGES

cascades of particles that originated deep in the heart of IceCube. Aided by artificial intelligence, they determined that, over a 10-year period, IceCube had picked up about 750 neutrinos from the Milky Way. "It's quite an achievement, when you think that Milky Way neutrinos account for only about 1 in 100 million events in our detector," says Hünnefeld.

These neutrinos were emitted from all across our Galaxy, a slender, flattened spiral of stars shaped much like a CD. "As yet, IceCube physicists can't tell whether these neutrinos come from unknown individual sources or are instead from a diffuse background that permeates the Galactic disc," explains Sclafani.

THE BIRTH OF NEUTRINO ASTRONOMY

A pedant might point out that these aren't the first neutrinos from our Galaxy to have been detected. Since the mid-1960s, much lower-energy neutrinos from the Sun – which is, of course, in the Milky Way – have been picked up.

Higher-energy neutrinos from Supernova 1987A, which exploded in 1987 in the Large Magellanic Cloud, have also been detected – although that's not in our Galaxy.

The crucial difference with this most recent detection is that not only is it the first time high-energy neutrinos from the Milky Way have been picked up, but it's also the first time that a 'map' of their Galactic distribution has been created. This is what justifies the claim that their detection marks the birth of neutrino astronomy.

One reason why the detection of these neutrinos is important is because they could tell us about mysterious cosmic particle accelerators, which can boost cosmic rays to phenomenally high energies beyond anything achievable through human technology.

Cosmic rays can't provide such information. Being electrically charged, their trajectories are bent so wildly by magnetic fields in space that, by the time they arrive on Earth, it's impossible to tell where they came from.

"By contrast, neutrinos travel in straight lines," says Sclafani. "And they can be created when cosmic rays slam into atomic nuclei close to their source. They therefore point back directly to the engine that creates cosmic rays."

Already, IceCube scientists have traced high-energy neutrinos back to two galaxies beyond the Milky Way: NGC 1068 (aka the Squid Galaxy) and TXS 0506+056. "It's a strange thing that we detected neutrinos from far beyond the Milky Way before neutrinos from our Galaxy," says Hünnefeld. "The explanation for this is that those two galaxies are prodigiously energetic objects, powered by supermassive black holes far more massive →

ABOVE LEFT Mirco Hünnefeld of TU Dortmund, is one of the physicists involved with the IceCube Neutrino Observatory

ABOVE RIGHT IceCube detected high-energy neutrinos from NGC 1068, a galaxy 47 million light-years from Earth, before it picked up any from the Milky Way

"PHYSICISTS HOPE TO PINPOINT MORE PRECISELY THE ORIGINS OF THE MILKY WAY NEUTRINOS"

RIGHT Steve Sclafani of the University of Maryland, is one of the scientists working on the IceCube neutrino-detection project

BELOW Supernova 1987A, the brightest spot in this image, is a source of previously detected neutrinos

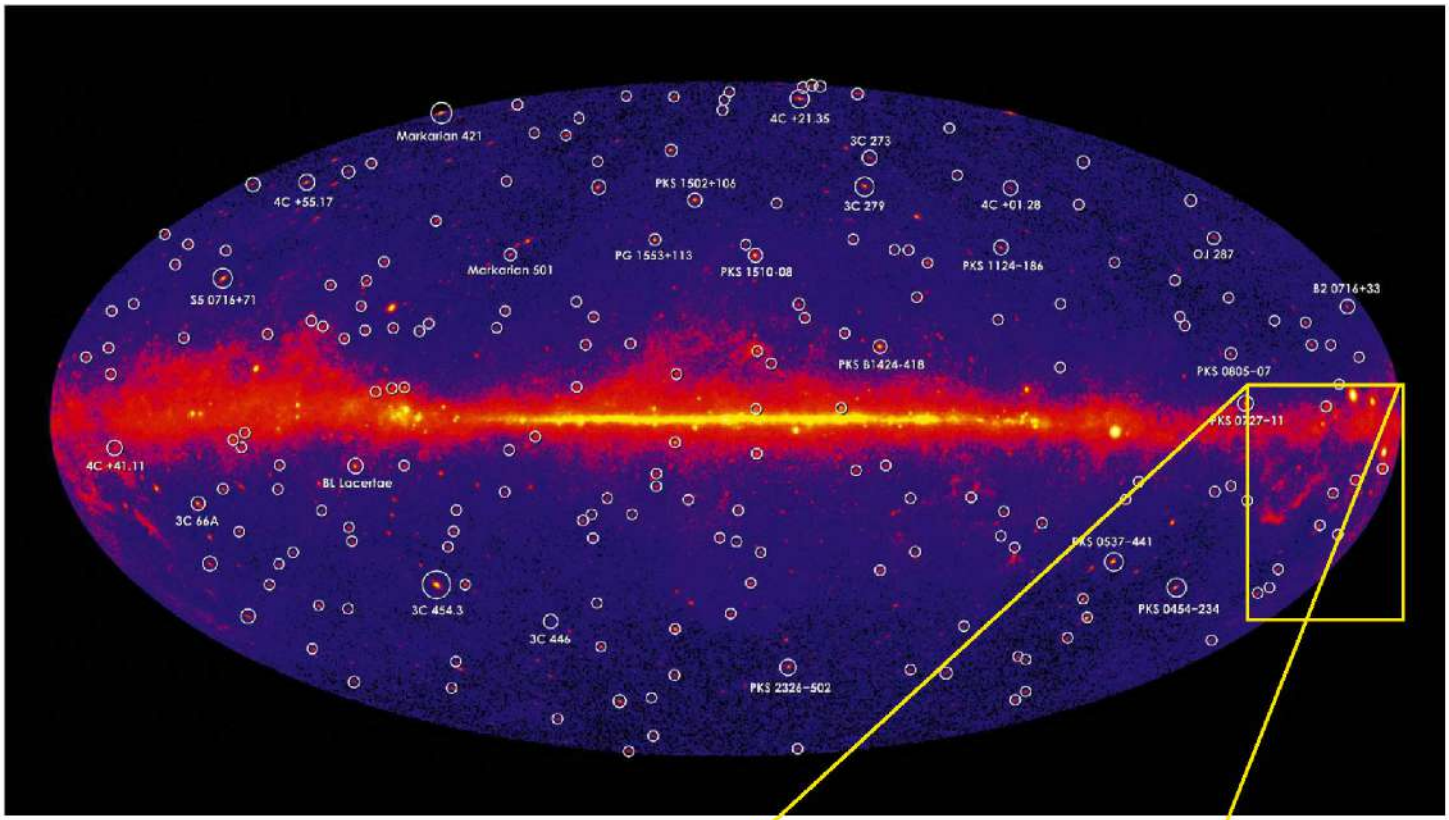
→ and far more active than Sagittarius A*, the one that lurks at the heart of the Milky Way."

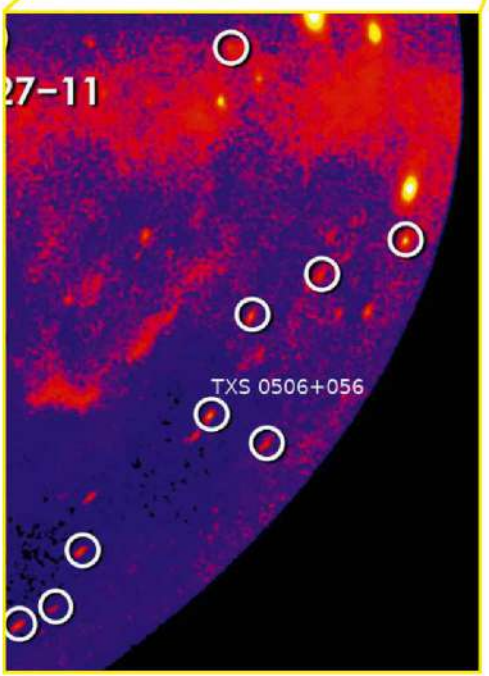
The details of how super-energetic cosmic rays are accelerated remain unknown. However, a general mechanism was proposed by Italian-American physicist Enrico Fermi in 1949. According to him, atomic nuclei (mostly hydrogen nuclei) bounce back and forth like ping-pong balls between shock fronts in interstellar gas, gradually gaining energy. Such shocks are thought to exist in the expanding debris of supernovae and in pulsar-wind nebulae – basically, supernova remnants energised by a hyper-compact, spinning stellar relic of the explosion known as a pulsar.

Shock fronts are also expected to exist in the high-speed 'jets' shooting from the poles of the supermassive black holes that power galaxies such as NGC 1068 and TXS 0506+056. "In the case of TXS 0506+056, a violent galaxy known as a 'blazar', the jet is pointing directly at us," says Sclafani. "So collisions between accelerated particles and nuclei in the local environment create neutrinos beamed in our direction."

It's thought that the neutrinos detected from the Milky Way come from sources such as supernova remnants and pulsar-wind nebulae, and from a diffuse background. Such a background is expected to be created by cosmic rays trapped by the Galactic magnetic field. The rays circulate in the disc of the Milky Way until they collide with an atomic nucleus in the gas and dust of the interstellar medium, creating high-energy neutrinos.

Such a neutrino background was predicted when astronomers observed a diffuse background of high-energy light coming from the Milky Way. They postulated that the light was caused by collisions between cosmic rays and atomic nuclei in the interstellar medium. "High-energy neutrinos, such





ABOVE AND LEFT
A plot of blazars – galaxies shooting jets of matter towards Earth – reveals the position of TXS 0506+056, another source of detected neutrinos

STEVE SCLAFANI, NASA/DOE/FERMI LAT COLLABORATION, ESO

as the ones IceCube has now detected, would be an inevitable by-product of such collisions," says Hünnefeld.

The IceCube physicists hope to pinpoint more precisely the origins of the Milky Way neutrinos when their experiment gets an upgrade, scheduled to happen in the winter of 2025/26. There are also longer-term plans to expand IceCube's target volume to 10km^3 of ice, and to incorporate new and more-sensitive photomultipliers.

In addition, the physicists hope to be able to detect not just Cherenkov radiation, but also radio waves from the cascades of particles created by neutrino collisions in the ice. The subatomic shrapnel created by the impact of a neutrino is skewed in terms of electric charge, because negatively charged electrons survive while positively charged positrons are quickly annihilated when they encounter particles of matter. The resultant fluctuating electric field creates radio waves – providing another potential avenue for detecting neutrinos.

A NEW WAY OF SEEING

Sclafani is excited about the future of neutrino astronomy. "We're the new kids on the block," he says. "It's like the early radio astronomers or gamma-ray astronomers, who had only really blurry vision. Now they have hugely sharpened their vision and can see a multitude of discrete celestial sources. That's what we want to achieve, too."

According to Sclafani, neutrino astronomy has huge potential. The environments close to the supermassive black holes that are responsible for accelerating cosmic rays in galaxies such as NGC 1068 and TXS 0506+056 are clogged with dense and turbulent super-hot matter.

"Light is blocked and simply can't get out, whereas neutrinos are unhindered and come straight to us," says Sclafani. "They represent the only way we can get information about conditions very close to supermassive black holes."

Hünnefeld agrees that the discovery marks a major milestone in astronomy. "It opens an entirely new window on the Universe," he says. "Now we have really big neutrino telescopes, we're starting to make rapid progress. It's truly an exhilarating time." SF

by MARCUS CHOWN
(@marcuschown) Marcus was a radio astronomer before becoming a science writer and journalist. His latest book is The One Thing You Need to Know *(£16.99, Michael O'Mara).*

Q&A

Email your questions to **questions@sciencefocus.com** or submit on X (formerly Twitter) at **@sciencefocus**

YOUR QUESTIONS ANSWERED

ESME NEWMAN, VIA EMAIL

IS IT TRUE THAT WE ALL HAVE A 'SLEEP ANIMAL'?

Have you taken one of those online quizzes that assigns you an animal based on your sleeping style? According to some, there are four types of sleep animal: wolf, lion, bear and dolphin. But in 2022, Fitbit introduced sleep profiles that identified users as giraffes, bears, dolphins, hedgehogs, parrots or tortoises.

These animals don't seem to relate to the sleeping habits of the people they're assigned to – unless those 'dolphin' sleepers only allow half of their brains to sleep at any one time, as the mammals do in the wild. You won't find any of those sleep animals in the scientific literature, though. Only two are generally accepted by the scientists: morning larks and night owls.

These refer to a person's chronotype, which is their natural preference for sleeping and waking across a 24-hour period. Chronotypes are thought to exist on a spectrum that runs from morning types (larks) to evening types (owls). About 14 per cent of adults are thought to be larks while 21 per cent are owls, with the rest of us falling somewhere between the two.

Studies have shown your cognitive abilities and your energy levels have links to your chronotype, with morning types more energetic and able to perform better on tasks before midday and evening types feeling a gradual increase in energy and ability over the morning and afternoon, before peaking nearer the end of the day.

Understanding your body's preference can help you plan your days around your natural sleep habits – if you have the ability to tweak the time you start work, for example, or your wake-up time isn't decided by when your kids get up.

There are genetic factors at play, though. Scientists have identified key 'clock' genes that predispose a person's chronotype toward 'morningness' or 'eveningness', or neither. But your chronotype is not fixed, like your eye colour. Large studies have shown

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DR HELEN SCALES
Marine biology

AMY ARTHUR
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DR NISH MANEK
Health and medicine

LUIS VILLAZON
Engineering and technology

PROF PETER BENTLEY
Technology

that chronotypes change over a lifetime. As children we tend to be early risers, but there's a sharp rise toward eveningness in teenagers. Then, after the age of about 20, we gradually become more lark-like, until, in our late 50s, we're getting up and going to bed about the same time we did when we were 10 or 11.

You're not completely at the mercy of your genetics and your developmental state, however. Your chronotype is heavily influenced by your environment, particularly the amount of light you see at different times of the day. This is because your body clock is constantly taking in information and adjusting your circadian rhythms. This process, known as entrainment, is how we learn to cope with new time zones and why jet lag doesn't last forever.

Morning light is especially key for setting sleeping patterns. The more morning light you're exposed to, the more likely you'll wake earlier the following day, and vice versa. So if you're prone to sleeping in on a Sunday morning, you're making it much

"ABOUT 14 PER CENT OF ADULTS ARE THOUGHT TO BE LARKS WHILE 21 PER CENT ARE OWLS"

harder to get up at an earlier time when Monday comes around.

If you fall toward the 'night owl' end of the spectrum you can alleviate some of the grogginess of getting up early by exposing yourself to a lot of light in the morning, even if it's artificial, and by adjusting your workload (where possible) so that the more demanding tasks fall later in the day. ***AA***

GETTY IMAGES X2 ILLUSTRATION: HARRIET NOBLE

FREDDIE HERBERT, CHELMSFORD

WHAT IS A BIOMETRIC PASSPORT?

A biometric passport contains a computer chip and an antenna. Like contactless credit cards, when the chip in the passport is placed within 4cm (1.5in) of another transmitting antenna, power is induced in the chip, allowing it to send and receive a signal.

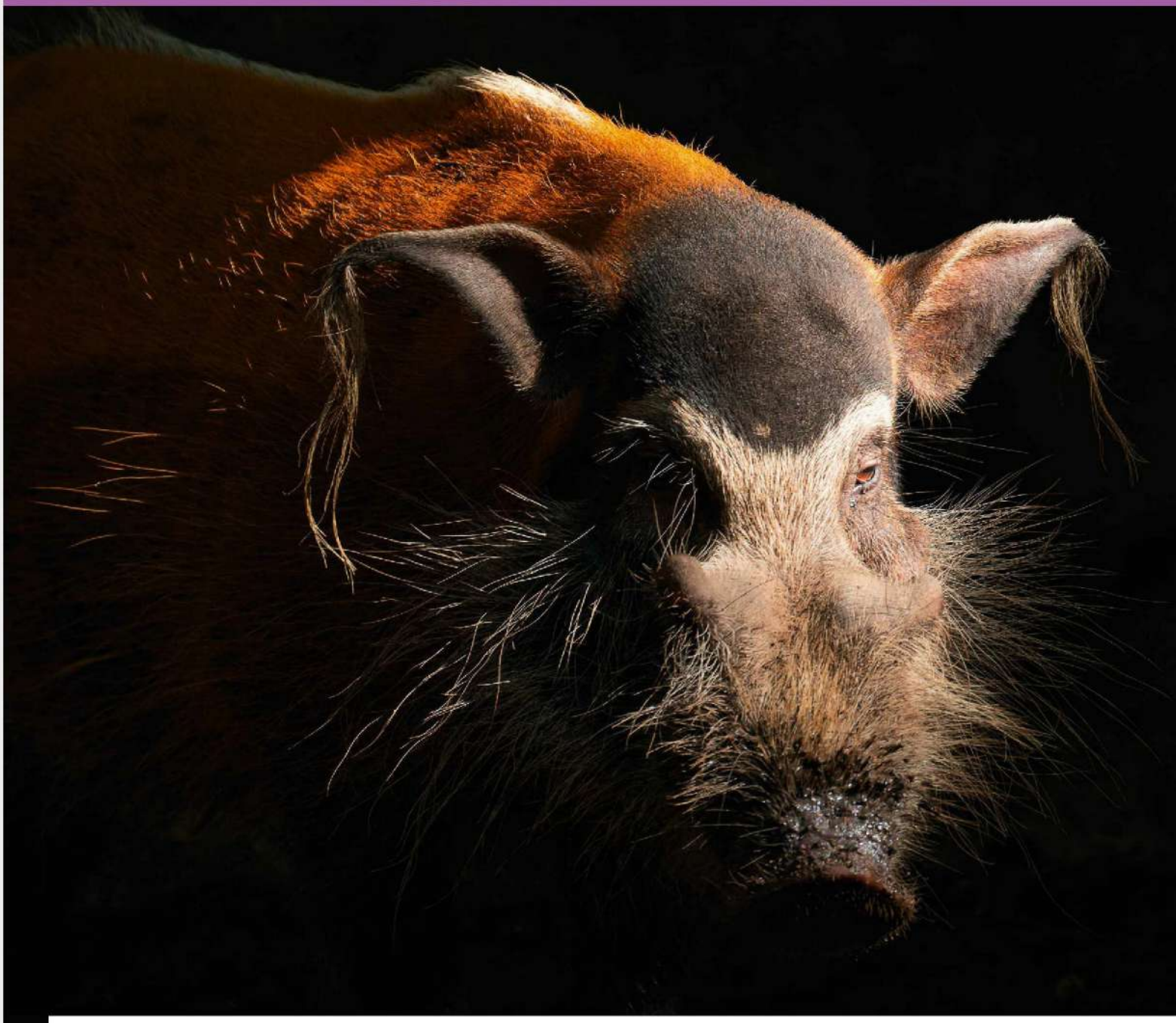
The chip in your passport contains your name, date of birth and passport details, as well as encrypted biometric information used for facial, retinal or fingerprint recognition. The passport inspection system compares these with the scanned traveller details at passport control. If they match, then the little doors open and you can pass through. ***PB***

HOPE MAXWELL, VIA EMAIL

WHY ARE ELECTRIC CARS SO EXPENSIVE?

There are several reasons. The first is that there's no economy of scale. While manufacturers have been making cars powered by internal combustion engines for over 100 years, mass-produced electric cars are still relatively new, with fewer factories able to make the specialised components. The costliest part of the electric car is the battery and worldwide shortages of lithium (an essential element in the lithium-ion batteries) have driven prices higher. Between 2020 and 2023 there was also a shortage of semiconductors (essential in these high-tech cars) caused by the COVID pandemic, extreme weather in Taiwan and the China-USA trade war, which pushed up prices even further. ***PB***

NATURE'S WEIRDEST CREATURES



RED RIVER HOG

Pigs are charismatic, smart animals, but this little piggy takes the ginger biscuit. The red river hog, otherwise known as the 'tufted pig', is a wild member of the pig family, found in western and central Africa.

With its striking red coat, it's the most colourful member of the pig family. Its vibrant pelt is topped off with a thin, white mane that runs the length of its back, on top of stocky, black legs and sturdy trotters. Its face is part ALF (the alien life form from the '80s American sitcom), part Dobby the house elf (from the *Harry Potter* stories). Whiskers protrude from the base of a long, black snout, while its jet-black eyes are framed by bold white markings. The contrasting marks are a form of camouflage, called disruptive coloration, which breaks up the animal's outline so it can blend in with the background.

Its ears, however, are the main event. Tapered triangles give way to spectacularly long tufts of hair, which frame the face and add a touch of wizard-chic to the animal's unconventional beauty.

Red river hogs live in small groups of around 4-20 animals, called sounders. They can be found in rainforests and the adjacent savannah, and often hang out near rivers and swamps. Each sounder is

led by a single boar, who watches over a harem of females and their youngsters. Weighing between 50 and 100kg (110-220lbs), they may be one of the smaller pig species, but they're feisty. Males fight off rivals by head butting, snout jabbing and whipping each other with their tails, and will readily defend their family from leopards, spotted hyaenas and pythons.

Within the group, individuals communicate with an inventive repertoire of grunts and squeals. They snooze the day away and then forage at night. Like all pigs, red river hogs are omnivores, devouring whatever they can find. Fruit, seeds, nuts, eggs, snails, carrion and lizards are all fair game, as are domestic animals and crops, such as goats and cassava. They use their teeth to dig for roots, bulbs and insects, and can swim and forage for water plants. They also have a penchant for the seeds of the Boko tree (*Balanites wilsoniana*), which they find, undigested, in the faeces of elephants and by following chimpanzees in the hope of coming upon fallen fruit.

Females give birth to up to six piglets between the end of the dry season in February and the middle of the rainy season in July. Mothers fashion a makeshift nest from dead leaves and dry grass, and care for the youngsters with the boar's protection. The piglets, which initially sprout dark-brown fur with yellow stripes and spots, are weaned at four months and develop their ginger coat two months later. The dark facial markings come with full maturity, about two years after that.

The species is not currently endangered, but as the hogs continue to encroach on agricultural land and the bushmeat trade intensifies, there are concerns that local populations could dwindle. Time then, for people to collab-boar-ate to help save this little piggy's bacon, before things go downhill. ***HP***

ALAMY X3

ZACHARY CARNEY, CHICHESTER

WHAT EFFECT DO ENERGY DRINKS HAVE ON MY BODY?

Energy drinks – from Red Bull to Monster Energy – have gained immense popularity as a quick and convenient way to give yourself a boost. One of the newest, PRIME Energy, which was founded by YouTubers Logan Paul and KSI, went viral when it launched earlier this year, but the high levels of caffeine in it have led to it being banned in some schools and facing scrutiny from lawmakers and health experts. But what does the science say about this and other energy drinks?

Different energy drinks contain different amounts of caffeine, but often much more than you'd find in a typical cup of instant coffee, which generally contains between 30-90mg. For example, in the UK, one 330ml can of Coca Cola contains 35mg of caffeine; a 250ml can of Red Bull contains 80mg; a 330ml can of PRIME Energy contains 140mg; and a 500ml can of Monster Energy contains 160mg.

Although the thought of such a quick, concentrated boost might be appealing, it's important to understand the impact these drinks have on your body. So let's see what happens when you drink one...

30 minutes after consumption... You might begin to experience a rapid increase in alertness and improved concentration due to the stimulant effect of the high dose of caffeine. Your heart rate and blood pressure may also rise, which can give you a sense of heightened energy. But this initial surge might also lead to restlessness, jitters and, in some cases, palpitations.

60 minutes after consumption... At this point, the peak caffeine levels in your bloodstream may have passed (although it will take around 5-6 hours for your body to achieve a 50 per cent reduction in the amount of caffeine in the bloodstream). You might start to experience a 'crash', with a sudden drop in energy levels. This can lead to feelings of fatigue, irritability and even headaches. The sugar content in energy drinks can contribute to this crash by causing a rapid increase and subsequent drop in blood sugar levels.

12 hours after consumption... By now, most of the caffeine has likely been metabolised and eliminated from your body. But the lingering effects might still make it harder to fall and stay asleep. If you drink caffeinated drinks regularly, you might experience some withdrawal symptoms about now, such as a headache and irritability.

Besides the caffeine, energy drinks also contain ingredients such as taurine, electrolytes, vitamins and thiamine. These are often included for marketing purposes and are unlikely to have significant health benefits, especially when balanced against the negative effects of caffeine and sugar. Most people get enough of these from their regular diets anyway.

Adults generally have a higher tolerance for caffeine, whereas children and adolescents tend to be more sensitive to it, which can lead to more pronounced side effects, such as increased heart rate, high blood pressure, anxiety and nervousness. Additionally, energy drinks can interfere with children's growth and development by disrupting their natural sleep patterns, potentially impacting their academic and social performance. The combination of caffeine and high sugar content might also lead to an increased risk of obesity in children and adolescents, and even early onset type 2 diabetes.

These energy drinks often make big promises. Some say they'll increase your energy and alertness, others offer extra nutrition, and some even claim to boost your athletic performance or powers of concentration. But once you cut through the hype, what you're mostly getting is just a stiff dose of sugar and caffeine – with plenty of side effects that you might prefer to avoid, especially if you're young. ***NM***

LEWIS MCKENZIE, VIA EMAIL

WHY DO DOGS LIKE STICKING THEIR HEADS OUT OF CAR WINDOWS?

The smell of the open road. The wind in your fur. The chance to look down on lesser, pavement-bound pups... There are many reasons why your pooch may choose to poke their snout through a moving car's window, but one thing's for sure, it's a sensory smorgasbord.

Although dogs see fewer hues and are often near-sighted, their field of view can be up to 250° (compared to our 180°) and they are better at perceiving motion. Dogs can detect more frames per second than us, meaning that while the hubcaps on an passing car look blurry to us, they could still look sharp to a canine passenger.

Scent, however, is where it's really at.

A dog's sense of smell is orders of magnitude greater than ours. Dog noses have 300 million smell receptors compared to our measly 6 million, and the brain region devoted to deciphering these chemical cues is 40 times larger. When we exhale, spent air goes out the way it came in. When dogs exhale, the air exits via slits on the side of the noses and then swirls around, creating currents that usher new odours into the schnoz. This enables dogs to sniff more or less continuously and helps to make scent their primary way of interpreting the world.

There's no debate. The rush of air from a moving car's open window is rocket fuel for the dog's sensory system, but there's another reason why so many canines may partake in window surfing. Dogs are complex creatures with needs that extend far beyond innate necessities, such as food, water and sex. So why do it? For the same reason some of us like to travel on open-top buses or ride in a convertible with the roof down. Because it's fun! ***HP***

KATIE ODLING, ST ALBANS

DO PLANES REALLY CRASH DUE TO ROUNDING ERRORS IN THE SOFTWARE?

On 4 June 1996, the maiden flight of the Ariane 5 launcher didn't go well. 40 seconds after take-off, the massive rocket suddenly veered from its flight path and exploded. The cause was a tiny software error: a floating-point number represented using 64 bits was converted to a 16-bit signed integer, but the conversion failed as the number was larger than 32,767 – the maximum that 16 bits could represent. This overflow error caused the software to dump debugging data into the area of memory being used to control the rocket's engines. The backup computer did no better, with the result that the rocket lost control and came to a fiery end.

In 2015 it was reported that tests had revealed a similar overflow error could shut down the electricity of Boeing 787 aircraft if their generator control units were on for 248 days continuously. Under these circumstances their software counters reached 2,147,483,647 – the maximum value for a 32-bit signed register. Turning them off and on would reset the counter to make them work again and, luckily, it never led to disasters, in the way the much faultier software of the 737 Max did, three years later.

While overflow errors like these are similar to rounding errors, there's a subtle difference. Instead of a number being too big, a rounding error is typically caused when a number is inaccurately calculated and stored in binary. For example, the results of some calculations are irrational numbers: like the number Pi (3.14159265...). It never ends so we have to approximate its value, perhaps as just 3.142. Even simple calculations such as 2/3 in decimal can't be written down precisely and may have to be the equivalent of 0.667 in binary. Continue to perform calculations like this and the tiny errors accumulate, until they add up to be significant.

One of the most notorious examples of this kind of error came in the Gulf War. A Patriot missile was launched to stop an incoming Scud missile, but instead struck a barracks, killing 28 soldiers and injuring many more. The cause was a rounding error in the tracking system that had accumulated until the missile was sent in a terrible direction. A calculation involving the time caused the error, which got worse the longer the system was on.

Software bugs such as these are easy to overlook and can be tragic in their results. But you don't even need the software to be buggy for accidents to happen. In May 2019 an experienced train driver unfamiliar with the new software in his train was attempting to restart the computer and instead accidentally accelerated to 15mph, crashing into another train and derailing his. Luckily no-one was injured. ***PB***

ALAMY, GETTY IMAGES ILLUSTRATIONS: HARRIET NOBLE, PETE LAWRENCE

BLAKE HOUSTON, VIA EMAIL

COULD YOU USE A YO-YO IN SPACE?

A yo-yo mainly relies on the laws of conservation of angular momentum to perform tricks. The basic up-and-down motion is caused by the string unwinding from the central axle, which causes the yo-yo body to spin rapidly. When it reaches the end of the string, the angular momentum of the body gives it the energy to wind the string up again, bringing the yo-yo back. This works just as well in microgravity, providing you keep the string taut. In 2012 NASA astronaut Don Pettit took a yo-yo on board the International Space Station and demonstrated several tricks, including some he invented that actually require weightlessness. ***LV***

ASTRONOMY FOR BEGINNERS

The view looking southeast at 22:30 GMT on 1 November, 21:30 GMT mid-November and 20:30 GMT on 30 November

JUPITER IN OPPOSITION

WHEN: MID-OCTOBER TO EARLY NOVEMBER

Jupiter is the largest planet in our Solar System, 11 times larger than Earth. It's now dominant in the night sky. If clear, Jupiter currently shines brighter than all other objects around it, save for the Moon when it's about. Jupiter reaches opposition on 3 November, when it'll appear at its brightest and best for 2023.

Jupiter is wonderful to view with a bit of optical aid. You can start small with binoculars, but steadiness is key. One trick is to use a household broom, inverted so the brush is pointing up and the tip of the handle is on the ground. You can steady the binoculars against the brush, using a cloth or towel to keep yourself and your binoculars clean. With a steadier view, you can focus better and see more as a result.

The planet has many moons, 95 at the last count. However, only four are large and bright enough to see easily with binoculars. Orbiting the planet, their positions relative to Jupiter vary. When separated from Jupiter, they should be visible through steadied binoculars.

With a small telescope, however, the moons will appear clearer, and Jupiter's face will be revealed. Relax and take time to let your eye get used to the view. Eventually, you'll see the two dark belts that encircle the planet's globe parallel to its equator: the north and south equatorial belts. Notice also that the planet's disc isn't round, but it appears squashed. This is because Jupiter is a rapidly spinning gas planet – one day on Jupiter lasts less than 10 hours!

If you have a 100mm or larger telescope, and if the timing is right, you may see an oval patch embedded within the south equatorial belt. This is the Great Red Spot, a persistent anticyclonic storm in Jupiter's atmosphere that some estimate may have been raging for at least 358 years. ***PL***

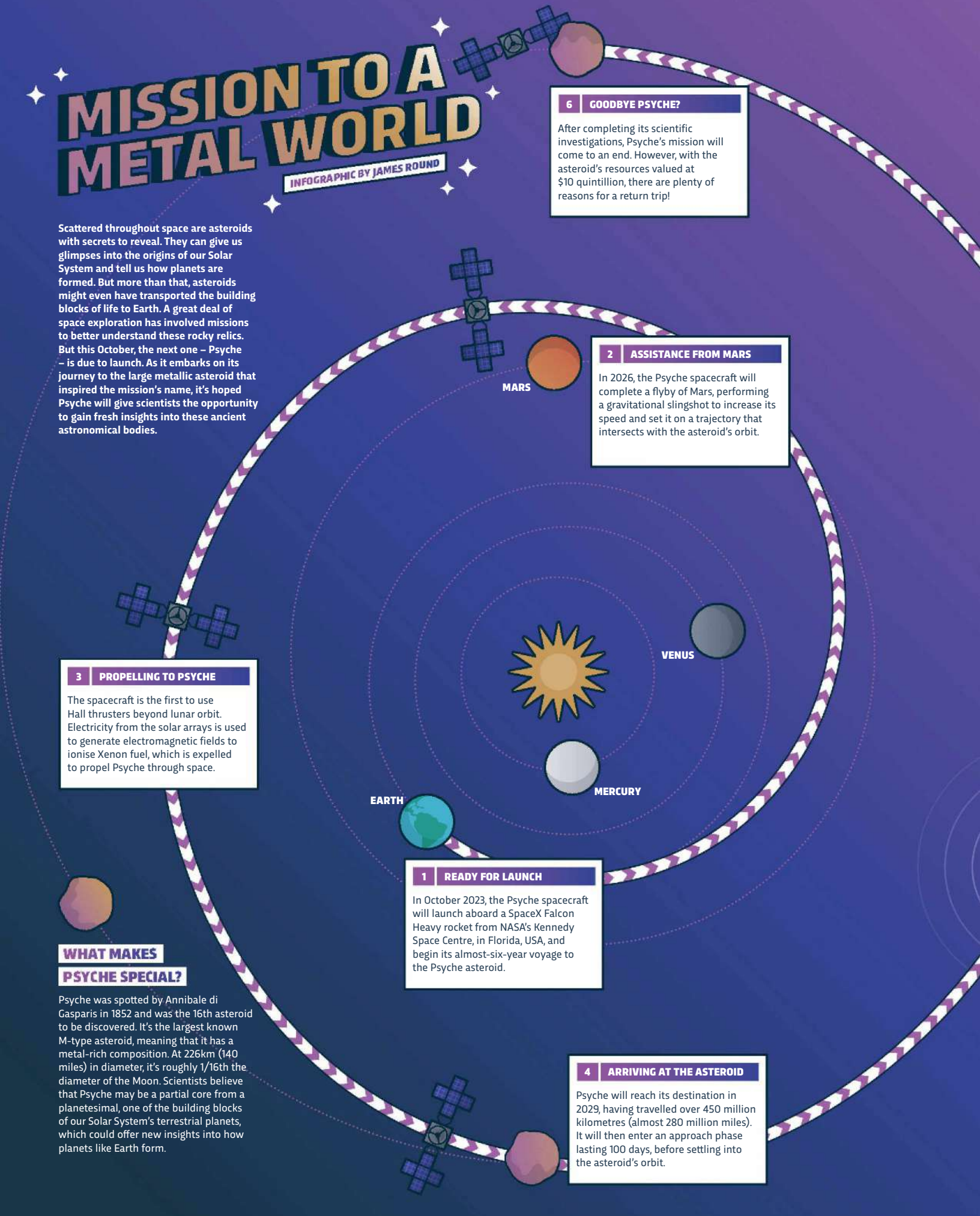
by PETE LAWRENCE
(@Avertedvision)
Pete is an astronomy expert and presenter on The Sky at Night.

WATCH *THE SKY AT NIGHT* ON BBC FOUR AND BBC IPLAYER
BBC FOUR

MISSION TO A METAL WORLD

INFOGRAPHIC BY JAMES ROUND

Scattered throughout space are asteroids with secrets to reveal. They can give us glimpses into the origins of our Solar System and tell us how planets are formed. But more than that, asteroids might even have transported the building blocks of life to Earth. A great deal of space exploration has involved missions to better understand these rocky relics. But this October, the next one – Psyche – is due to launch. As it embarks on its journey to the large metallic asteroid that inspired the mission's name, it's hoped Psyche will give scientists the opportunity to gain fresh insights into these ancient astronomical bodies.



1 READY FOR LAUNCH

In October 2023, the Psyche spacecraft will launch aboard a SpaceX Falcon Heavy rocket from NASA's Kennedy Space Centre, in Florida, USA, and begin its almost-six-year voyage to the Psyche asteroid.

2 ASSISTANCE FROM MARS

In 2026, the Psyche spacecraft will complete a flyby of Mars, performing a gravitational slingshot to increase its speed and set it on a trajectory that intersects with the asteroid's orbit.

3 PROPELLING TO PSYCHE

The spacecraft is the first to use Hall thrusters beyond lunar orbit. Electricity from the solar arrays is used to generate electromagnetic fields to ionise Xenon fuel, which is expelled to propel Psyche through space.

4 ARRIVING AT THE ASTEROID

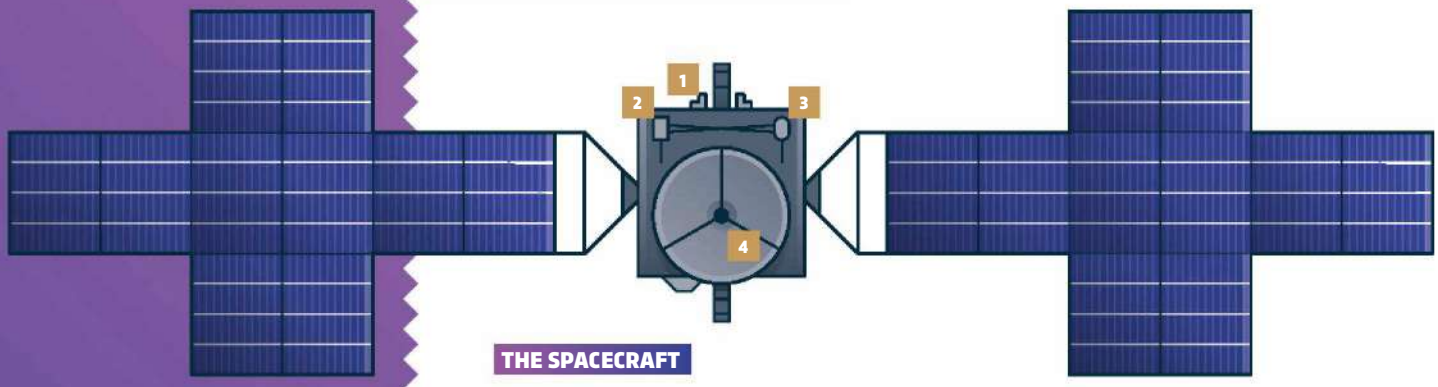
Psyche will reach its destination in 2029, having travelled over 450 million kilometres (almost 280 million miles). It will then enter an approach phase lasting 100 days, before settling into the asteroid's orbit.

6 GOODBYE PSYCHE?

After completing its scientific investigations, Psyche's mission will come to an end. However, with the asteroid's resources valued at $10 quintillion, there are plenty of reasons for a return trip!

WHAT MAKES PSYCHE SPECIAL?

Psyche was spotted by Annibale di Gasparis in 1852 and was the 16th asteroid to be discovered. It's the largest known M-type asteroid, meaning that it has a metal-rich composition. At 226km (140 miles) in diameter, it's roughly 1/16th the diameter of the Moon. Scientists believe that Psyche may be a partial core from a planetesimal, one of the building blocks of our Solar System's terrestrial planets, which could offer new insights into how planets like Earth form.



THE SPACECRAFT

First approved for flight by NASA in 2017, with construction completed in 2021, Psyche consists of a body attached to two solar arrays and is about the size of a tennis court. The spacecraft contains a number of innovative tools to help scientists better understand its namesake asteroid...

LENGTH AND WIDTH
24m (81ft) x 7m (24ft)

SPACECRAFT COST
~$670 million (~£537m)

1

Multispectral Imager

Two cameras with a variety of filters and lenses will document the asteroid in order to understand its composition, and provide a topographical map of its surface.

2

Spectrometer

This gamma-ray and neutron spectrometer will measure the asteroid's elemental composition, to help explain its formation and how it has changed over time.

3

Magnetometer

These two high-sensitivity sensors will be trying to detect and measure the remains of an ancient magnetic field, which could reveal insights into the asteroid's origins.

4

Telecommunications

As well as being used to send commands to the spacecraft, this system will measure changes in radio waves to determine the asteroid's rotation, wobble, mass and gravity field.

THE MISSION

The asteroid's physical characteristics and orbital parameters are not fully known. To ensure the mission's safety and success, the spacecraft will move through a series of progressively lower orbits during its scientific operations, building a better understanding of the asteroid in the process.

SCIENTIFIC MISSION
21 months

TOTAL ORBITS
1,256

ORBIT A

Characterisation

700km (430 miles)
41 orbits
56 days

The first phase of orbits will be used to detect the asteroid's magnetic field and model its gravity field, in order to plan the spacecraft's lower orbits.

ORBIT B

Topography

290km (180 miles)
169 orbits
80 days

Psyche's second phase of orbits will have the best lighting conditions in order to create a topographical map of the metal-rich asteroid.

ORBIT C

Gravity science

170km (105 miles)
362 orbits
100 days

The third phase of orbits offers the best opportunity to conduct gravity science. The Psyche spacecraft will also continue magnetic field observations.

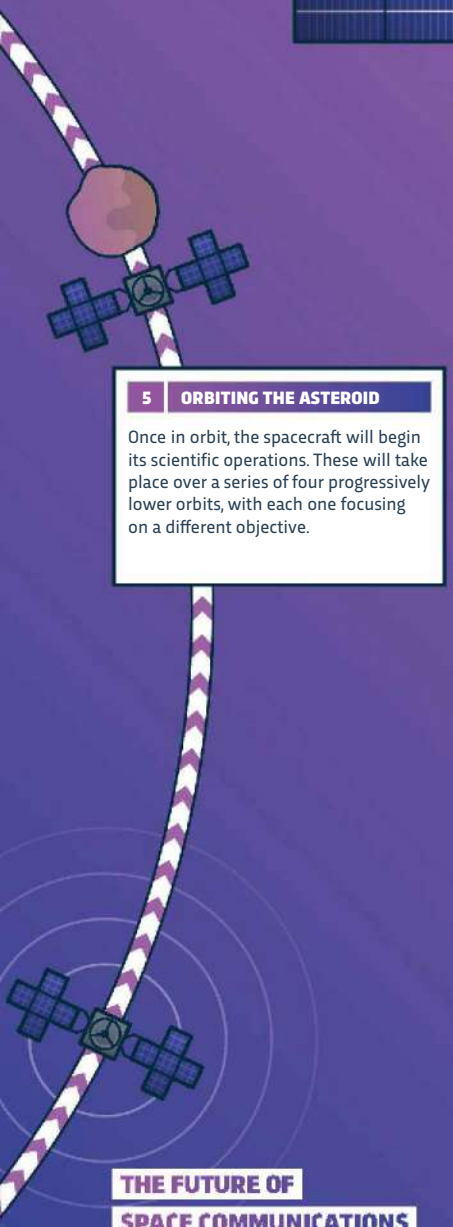
ORBIT D

Elemental mapping

85km (52 miles)
684 orbits
100 days

As the spacecraft reaches the closest phase of orbits, it will begin investigations into the chemical composition of the asteroid.

SOURCES NASA, JPL, Space.com, The Planetary Society, Wikipedia, Arizona State University, *Smithsonian Magazine*.



5 ORBITING THE ASTEROID

Once in orbit, the spacecraft will begin its scientific operations. These will take place over a series of four progressively lower orbits, with each one focusing on a different objective.

THE FUTURE OF SPACE COMMUNICATIONS

In addition to the mission's primary objectives, the Psyche spacecraft will also be testing a new communications technology. NASA's Deep Space Optical Communication experiment uses a laser to send messages by encoding the data into photons. Using light rather than radio waves allows for significantly more bandwidth, which will enable future missions to Mars and beyond to transmit large amounts of data, images and video.

DEAR DOCTOR

WHY ARE SOME EMOTIONS CONTAGIOUS?

If you've ever been in a jolly mood, with a spring in your step, then met up with a friend who is feeling grumpy, you'll know how contagious emotions can be. Before you know it, you realise that you're feeling down too. Happily, it can work the other way around too – when you've been sad, perhaps your friend's bubbliness has helped to lighten your mood.

Psychologists have shown that when people interact, a lot of mimicry goes on without us even realising it – from body language, to speech rate and pitch, to facial expressions. This is especially the case when we're interacting with someone we know and care about. A lot of these processes have to do with effective communication and mutual understanding. One way we make sense of other people's feelings is to simulate those feelings in our own mind. The net result of this mirroring is that we can infect each other with our emotions.

You might wonder who wins out – if you're feeling happy and your friend is feeling sad, and you meet up, do you succumb to their sadness or do they catch your happiness? Part of the answer is likely to come down to their and your levels of expressiveness and receptiveness.

Everyone varies in how emotionally expressive and suggestible they are. If you smile a lot when you're happy, you're more likely to infect your friend. Likewise, if your friend is suggestible and more prone to facial mimicry, then they'll be more likely to catch your smiles and start feeling happier (researchers in Germany showed that people who tend to mimic facial expressions are more prone to catching other people's emotions).

That isn't to say that facial expressions are the only way for emotions to spread. For instance, there's evidence that fear has a smell, and that smelling the sweat of an anxious person can trigger activity in parts of the brain involved in empathy and processing emotions.

In fact, for emotions to spread, there doesn't need to be any physical contact at all. Researchers have shown that emotions can spread through social media. People who are exposed to more negative posts are more likely to go and post something negative themselves.

Whether or not you find it grating to encounter an emotion opposite to the one you're feeling will come down to the context. Generally speaking, it can be soothing to find we're on the same emotional wavelength as others. Hence the popularity of listening to sad music when we're feeling down, or the appeal of wallowing in heartache with a sympathetic friend.

If and when you encounter an opposite emotion to your own, the experience will likely vary depending on how invested you are in that other person or people. If you care about them, you'll be more motivated to make an emotional shift to match their state (research shows we're more likely to mirror the emotions of people we like). Conversely, if you're feeling sad and a bunch of strangers sit near you on the bus laughing their heads off, you're likely to find it really annoying. ***CJ***

MALIKA NIXON, HEREFORD

HOW DO EELS REPRODUCE?

There are around 15 species of eels in the *Anguillidae* family, all of them long, snake-shaped fish and most of them migrating between the ocean and freshwaters inland during different parts of their lives.

The most remarkable journey is made by the European eel, (*Anguilla anguillla*). Born in the Sargasso Sea, in the central Atlantic, they hatch into transparent larvae that look like leaves with tiny fish heads stuck on. They drift for thousands of miles on Atlantic currents and arrive on the shores of eastern Europe where they transform into bootlace-sized young, known as glass eels or elvers. They mature in shallow coastal seas and eventually change colour to become larger yellow eels before migrating along rivers and into lakes. For decades, eels stay in inland freshwaters, before changing colour again to become metre-long silver eels.

Silver eels are the final life stage and have the intrepid task of retracing their paths from decades earlier, and swimming all the way back to the Sargasso Sea. It's only when they approach the spawning waters that males and females mature and their sexual organs develop.

For years, the epic life cycle of European eels remained an unproven theory. It was only in 2022 that scientists tracked silver eels to their spawning grounds, where the females release millions of eggs that are externally fertilised by the male eels.

The next big question is what the future will hold for eels. The number of glass eels arriving at European coasts has plummeted by more than 95 per cent in recent years, and the species is highly endangered. They face many problems, including dams blocking their migration routes and illegal trading of glass eels to rear in fish farms. ***HS***

ANTHONY MCKINNEY, VIA EMAIL

WHAT HAPPENS WHEN I STOP DRINKING ALCOHOL?

Embarking on a journey of sobriety, however much you drink, can have profound effects on your body, leading to positive changes over days, weeks, months, and years.

Within the first few days of giving up alcohol, your body should begin to respond positively. Alcohol's dehydrating effect starts to reverse, leading to improved hydration levels. This can result in clearer skin and enhanced energy levels. Moreover, your liver, which bears the brunt of alcohol metabolism, gets a respite, allowing it to focus on detoxification and repair. As alcohol exits your system, your sleep quality may improve, leading to more restful nights. If you've been a regular drinker, you might also experience temporary acute withdrawal symptoms in the early days – if these are severe or you struggle to cope, seek medical help.

After weeks of sobriety, the benefits become more evident. Your immune system, which alcohol can suppress, starts to regain strength. Mentally, you'll likely experience enhanced clarity and concentration as the fog of alcohol's impact on the brain lifts. While withdrawal symptoms such as cravings and lethargy can last a couple of weeks, they fade considerably by this point.

After months of sobriety, your liver function will be significantly improved. Liver enzymes normalise, reducing the risk of conditions like fatty liver disease and cirrhosis. Without alcohol's empty calories, you might lose some weight. Additionally, your cardiovascular system benefits, as blood pressure stabilises, and the risk of heart-related issues decreases. Getting sober can also help you regulate your emotions more effectively a few months down the line.

Years of sobriety bring about remarkable changes to your health and wellbeing. The reduced risk of chronic conditions such as liver diseases, pancreatitis, and certain cancers becomes more pronounced. Cognitive function improves, with memory and mental agility showing signs of recovery. Long-term emotional wellbeing often receives a boost too, as anxiety and depression symptoms diminish, and sexual function may also improve. Many sober people say they experience a boost in self-esteem, but the stabilised sleep patterns alone can have a significant impact on your physical and mental health.

It's important to emphasise that going sober is unlikely to be easy if you're a heavy drinker or alcoholic. Almost everyone will have moments where they feel worse before they feel better, whether it's emotionally or physically. So it's important to get the right support around you. But if you can do it, the benefits to your physical and emotional wellbeing can be huge. ***NM***

QUESTION OF THE MONTH

SOPHIE, VIA EMAIL

WHAT WOULD HAPPEN TO HUMAN EVOLUTION IF WE LIVED IN SPACE PERMANENTLY?

If humanity suddenly had to abandon Earth on a fleet of space-arks, we would probably go extinct before evolution by natural selection had time to alter our bodies to cope with the new environment. Even if we assume that air, food and water could all be synthesised and recycled indefinitely, a microgravity environment currently causes astronauts aboard the International Space Station to lose about one per cent of their bone density each month, even with strenuous daily workouts. After a few years of this, everyone would be suffering from severe osteoporosis. If our voyage took us into deep space, we would also need to worry about radiation. Galactic cosmic rays would bathe us in roughly 250 times the normal background radiation we receive on Earth and a single solar flare could be strong enough to cause radiation poisoning.

In order to survive this for decades at a time, we would need spaceships with more Earth-like environments than current spacecraft have. Large-diameter rotating habitats to simulate gravity and thick shielding to block the radiation would be the bare minimum. But if conditions on the spacecraft are just like Earth, there would be no evolutionary pressure to cause our bodies to adapt.

Society would certainly evolve though. Surrounded by danger and acutely dependent on technology, we might develop much more authoritarian societies where each person must perform their allocated role without question and be ready to sacrifice themselves for the benefit of the species. This would be too important to leave to the unpredictability of democratic, free-market capitalism, so perhaps a rigid hierarchy, akin to the regimes aboard 19th century sailing ships would emerge. ***LV***

WINNER

The winner of next issue's *Question of the Month* wins a **trio of hardback popular-science books**: *Fantastic Numbers and Where to Find Them* by Antonio Padilla; *Elusive* by Frank Close; and *Fevered Planet* by John Vidal, worth £60.

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

GETTY IMAGES X2, ALAMY ILLUSTRATION: HARRIET NOBLE

THE EXPLAINER

THE SCIENCE OF MONSTERS

REAL-LIFE EXPLANATIONS FOR THE CREATURES THAT HAUNT OUR IMAGINATIONS

Tales of fantastical beasts and supernatural beings are as old as human history. From werewolves and vampires to yetis and deep-sea monsters, mythical creatures have inspired countless folk tales and works of culture – not to mention some elaborate hoaxes. They have also driven many intrepid explorers into the wilderness, in the hope of gathering definitive proof of the existence of such beings. Several have been identified as real species, some have been confirmed as fiction, and still others remain the subject of passionate debate. Creatures not yet described by science are known as cryptids – denoting their 'hidden' status – and the study of these mysterious animals is cryptozoology. But what's the real science behind mythical creatures?

ALAMY, GETTY IMAGES X2

Vampires

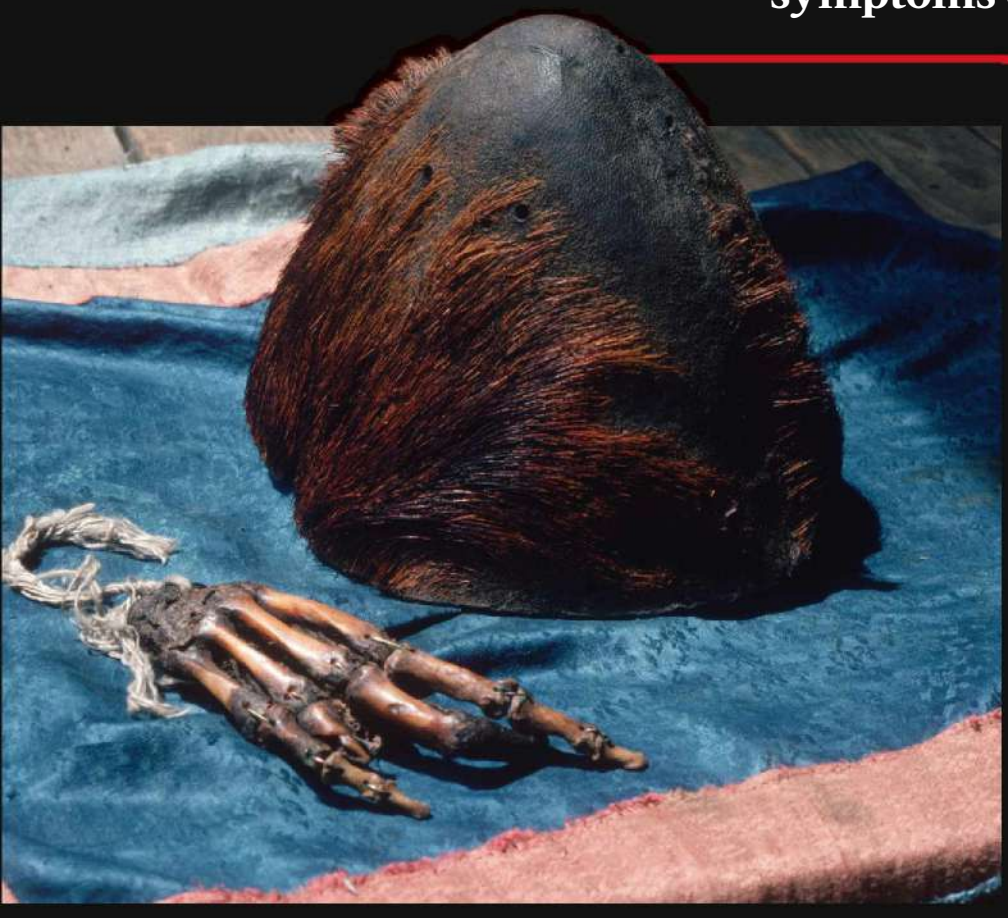
Vampires have been depicted many times in literature, film and television. But scientists have speculated that the legend originated in one of several very real medical conditions.

The most commonly cited is porphyria, a rare group of disorders that cause irregularities in the production of haem (or heme), a molecule found in blood. Porphyria leads to the build-up of toxins in the skin, rendering sufferers sensitive to light and causing deterioration of the lips and gums, possibly explaining portrayals of vampires as fanged or facially disfigured.

Another suggestion is that descriptions of vampires echo some symptoms experienced by people suffering from tuberculosis, including pale skin and blood around the mouth. Tuberculosis is highly contagious, perhaps leading to the belief that vampirism is transmitted by drinking blood.

However, there are some people that think the vampire legend resulted from misunderstandings and fears about death and decomposition. The skin contracts after death, creating the illusion that hair and fingernails continue to grow. Some real animals – including vampire bats and leeches – do feed on blood, though there's little evidence that these creatures inspired the myth.

> "Descriptions of vampires echo some symptoms of tuberculosis"



The yeti

The centuries-old legend of a large, two-legged hairy creature with huge feet roaming the Himalayas has long captured the imaginations of explorers and cryptozoologists around the world.

An ape-like glacier spirit appears in myths of the Lepcha people indigenous to Nepal, Bhutan and northeast India. But the yeti achieved global notoriety in the early 20th century when sightings were reported by British mountaineers, some of whom obtained specimens of fur, bone and skin. Modern science has debunked the claims that these samples came from yetis, however.

DNA analyses in 2014 and 2017 found that alleged yeti specimens, in fact, belonged to brown bears, black bears, polar bears and other – very real – mammals.

ABOVE The vampire bat of the Americas drinks blood, but vampire legends predate Columbus
LEFT The scalp and hand of a 'yeti' at a monastery in Nepal. Most such relics prove to come from bears

Sea serpents

Tales of giant sea serpents date back to antiquity, but became increasingly common when Europeans began exploring the oceans more widely in the 15th century. Scientists think that a good candidate for the source of such stories is the giant oarfish, the world's largest bony fish, which can grow up to 8m (26ft) long and has a habit of swimming vertically.

Found in temperate and tropical waters, this giant fish spends most of its life in the deep ocean, coming to the surface only during times of stress. Some reports suggest that oarfish ascend in response to seismic activity before an earthquake or tsunami, which could explain the myth that sea serpents are harbingers of doom.

Another possible explanation for sea serpent sighting is that accounts described marine animals entangled in fishing gear, writhing around while attempting to free themselves. A fishing rope or net might, in such circumstances, look like the long, coiled body of a serpent.

The griffin

Legends of a strange, winged creature with the body of a lion and the head of an eagle date back to the 7th century BC in Central Asia.

It's been suggested that the inspiration for this mythical creature, which was said to guard golden treasures, came from early discoveries of dinosaur fossils.

One mooted species was *Protoceratops*, a beaked dinosaur that lived in Asia between 75 and 71 million years ago. Its fossilised bones were uncovered by Scythian gold miners in the Gobi Desert around 2,000 years ago. But descriptions of the griffin predate these finds.

ABOVE The giant oarfish, which grows to 8m long, may have inspired tales of vast sea serpents that terrified early explorers
LEFT This bronze griffin figure dates back to ancient Greece, showing just how long the legendary creature has endured

Mermaids

Strange, often beautiful aquatic creatures with human torsos and fish-like tails have appeared in folklore for millennia. The myth may have originated in Syria around 1000 BC in the form of Atargatis, a fertility goddess who jumped into a lake and turned into a fish. Much later, European sailors exploring the high seas in the 15th century returned with reports of mermaid sightings. Christopher Columbus's description of a mermaid near what's now Haiti in 1493 suggests the real animals these explorers probably encountered were "not so beautiful as they are said to be, for their faces had some masculine traits".

The creatures such sailors saw were most likely manatees and dugongs – large, herbivorous marine mammals also known as sea cows. Growing about 3-4m (9-13ft) long, they sometimes rise above the surface by 'standing' on their tails. Another factor possibly contributing to sailors' visions was scurvy. Symptoms of this disease that afflicted seafarers on long voyages, and which is caused by vitamin C deficiency, include hallucinations. Combine lonely sailors with scurvy-induced visions and a roughly human-sized marine mammal, and you can imagine how tales of mermaids might have evolved.

"Sailors in the Middle Ages brought tusks to Europe and sold them as unicorn horns"

Unicorns

Often portrayed as a white horse with a single, spiral horn sprouting from its forehead, the unicorn is one of the most famous mythical creatures. The earliest depictions of unicorns date from around 3300 BC in South Asia, and were probably based on aurochs, an extinct two-horned wild ox.

A 3rd-century BC mistranslation of the Hebrew word for aurochs (or possibly oryx), *re'em*, to the Greek word *monokeros*, 'one horn', might explain how the later unicorn myth originated.

The legend gained traction in the Middle Ages when sailors brought tusks to Europe and sold them as unicorn horns. In fact, such horns invariably came from narwhals, a medium-sized whale with a single tusk – actually an elongated, spiral-growing canine tooth – up to 3m long.

FIVE FAMOUS HOAXES

1.

BIGFOOT

In 1958, a local newspaper reported the discovery of giant footprints in Bluff Creek, California, attributed to a Bigfoot (or Sasquatch). The footprints were created as a prank by Ray Wallace – a fact revealed by his son only after his death in 2002. The famous footage of a 'Bigfoot' (above) shot by Roger Patterson and Robert Gimlin, released in 1967, was also shot in Bluff Creek.

2.

THE FIJI MERMAID

In 1822, American sea captain Samuel Barrett returned from a voyage with a mummified mermaid, which was displayed in New York, Boston and London. It turned out to be a composite created by Japanese fishermen, with the head and torso of a monkey sewn on to a fish's body and tail.

3.

THE LOCH NESS MONSTER

A photo of the Loch Ness Monster taken by British surgeon Colonel Robert Wilson in 1934 was shown to be a hoax 60 years later. The photo was faked using a plastic head and neck fixed to a toy submarine.

4.

THE CARDIFF GIANT

In 1869, construction workers uncovered a 3m (9ft) tall, 1,300kg (2,800lb) 'petrified man' on a farm in Cardiff, New York. The so-called Cardiff Giant was created by George Hull, who commissioned the stone man to be sculpted out of gypsum and buried, so that workers he'd hired to dig a well could unearth it. He confessed to the fakery later that year.

5.

THE COTTINGLEY FAIRIES

Photos taken by cousins Elsie Wright and Frances Griffiths in Cottingley, Yorkshire, in the early 20th century seemed to show the girls with fairies. The pictures were met with both awe and scepticism. But over 60 years later, the pair admitted the fairies were paper cut-outs from a children's book.

The kraken

A giant, octopus-like creature that wrecks ships, the kraken originated in Scandinavian folklore around the turn of the 18th century, but tales of enormous tentacled beasts have long been told around the world.

In this case, reality isn't so far from myth: two species of enormous, deep-ocean-dwelling squid have been discovered that may explain the origin of the tales. The giant squid, which can grow to 13m (42ft) long, was first described by scientists in the late 19th century, while the colossal squid, discovered in the early 20th century, grows to around 10m (32ft). Living at such great depths, these creatures are difficult to study and relatively little is known about their habits, although analysis of their stomach contents has revealed that they hunt fish and smaller squid, not sailors. Their main predators are sperm whales, and sucker marks on living whales hint at epic battles between cephalopods and cetaceans.

Despite their large size, such squid are unlikely to have the ability or inclination to attack large vessels. Even so, it's easy to understand why seeing one of these beasts would strike fear into the hearts of sailors.

"Tales of enormous tentacled beasts have long been told around the world"

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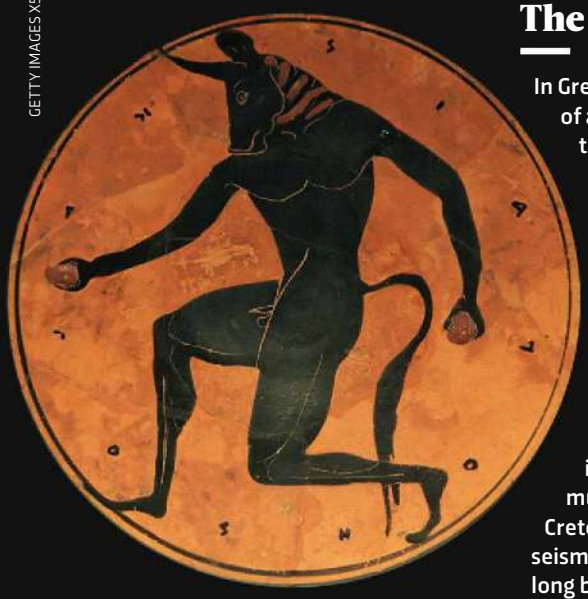

The minotaur

In Greek mythology, the Minotaur was a creature with the head of a bull and the body of a man, which lived underground at the centre of a maze called the Labyrinth. The story in its earliest form dates back to the Bronze Age Minoan civilisation on the island of Crete. However, the depiction of the Minotaur as a human-bull hybrid came later; it was originally described simply as a rage-filled beast that lived below ground and caused destruction above.

This gives us a clue to the origin of the Minotaur, which could have provided an explanation for devastating earthquakes. Crete lies directly above a major subduction zone – a region where one tectonic plate slides beneath another, causing tremors. The island is on the small Aegean Plate, which is being lifted as the much larger African Plate subducts beneath it. As a result, Crete has been subjected to many major earthquakes. Such seismic activity may have spawned the myth of the Minotaur – long before the science of tectonics developed.

by **DR CLAIRE ASHER** *(@claireasher)*

Claire is a science communicator and co-author (with Chris Forman) of Brave Green World *(£25, MIT Press).*

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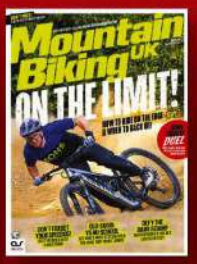

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CROSSWORD

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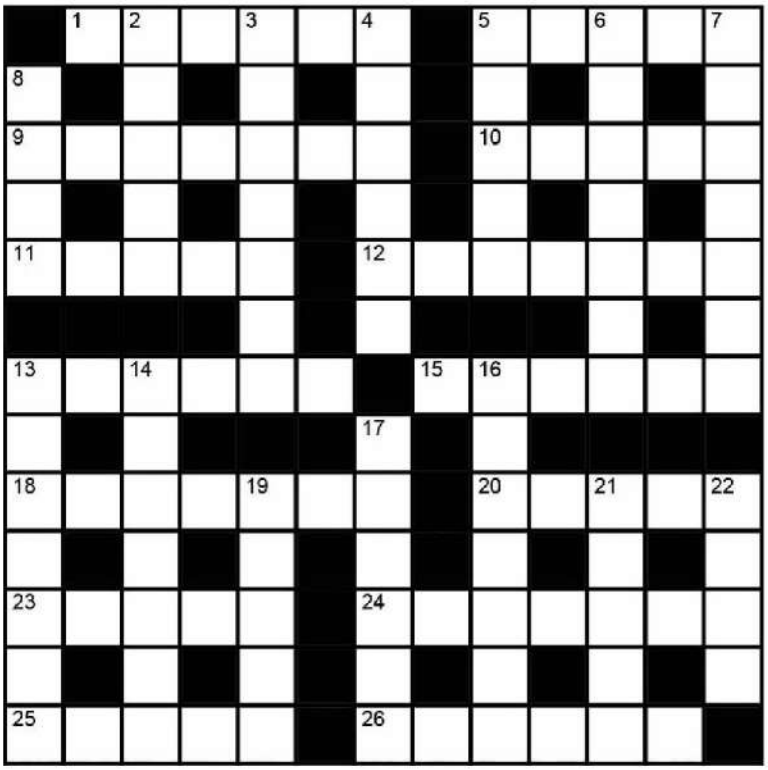

ACROSS

1 Box on right shows sign of blast (6)
5 Scratching head during fire in lift (5)
9 Furiously nag English socialist, getting annoyed (7)
10 City company has atmosphere (5)
11 Husky, say, or another animal (5)
12 Coming down from top of stairs (7)
13 Helping removing Republican concoction (6)
15 Oppose article (6)
18 Afterwards take a liberal to one side (7)
20 Boy with a right to navigation aid (5)
23 Records are very small, not initially large (5)
24 Appropriate time for a greeting (4,3)
25 Son got up first to get flowers (5)
26 Sensitive offer (6)

DOWN

2 OK bloke (5)
3 Poor Ted set off missile (7)
4 The puzzle of the kitchen? (6)
5 Graduate gets prisoner something for breakfast (5)
6 Hole in old tree returning diamonds (7)
7 Nevertheless, time for an idea (7)
8 Some loathing to curse (4)
13 Father left to maintain complex procedure (7)
14 New test includes an upper-class disease (7)
16 Instrument for singer with nothing on (7)
17 Struggle has student escape (6)
19 Controls laws (5)
21 Elbow, bare, takes force (5)
22 Beams in lift, by the sound of it (4)

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

GETTY IMAGES

NEXT ISSUE

OCTOPUSES' GARDEN

Dive into the undersea nursery where octopi spend their formative years

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JUST LIKE BEING ON THE MOON

Meet the scientists simulating the lunar landscape here on Earth

ON SALE 9 NOVEMBER

SF

POPCORN SCIENCE

Could your memories be instantly erased?

Doctor Who's skills extend to wiping people's memories. But does that ring a bell with real-world research?

by STEPHEN KELLY

It has been 15 years since Catherine Tate's fan-favourite Donna Noble left *Doctor Who*. Perhaps you remember it like it was only yesterday, which is something that can't be said for Donna herself. David Tennant's Doctor was forced to erase her memories of their time together, lest her puny human brain burn out from too much Time Lord knowledge. You may be shocked to hear, however, that there are doubts over *Doctor Who*'s scientific rigour.

"We don't know the ultimate capacity for human memory," says neuroscientist Dr Dean Burnett, author of *Emotional Ignorance: Lost and Found in the Science of Emotion*. "No one's lived long enough to fill it, for a start. If you did replicate the human senses in a computer and stored everything that you got from a live feed, it would fill up a hard drive pretty quickly. But that's not how memories work. We don't remember every single element of every experience we have of every waking moment. Our brains are a lot more discrete."

Nevertheless, the idea of wiping someone's memory isn't entirely implausible, points out Burnett.

"I think if you ran a powerful-enough electric current through the main storage regions of the brain, then that would scramble things," he says. "How you would do that safely – to the point where you don't lose vital memories, or the ability to remember new things – is another matter though."

The idea that you can eliminate specific memories – *à la* the Doctor – is a far more fantastical concept, however.

"We can't look at someone's brain and say, 'Okay, here's a memory of when they got their first bike'," says Burnett. "The best we could do is to look at someone's brain in a scanner to see what parts are activated when they think of that bike. And even then it's tricky because your frontal lobe, which is retrieving the memory, will be active, but there'll be lots of different parts of the brain being triggered simultaneously too. In one part may be the memory for 'bike', and in another part is 'childhood, 1987'. The memory is not in one location. That's why it's so difficult."

Of course, if anyone could figure out how to isolate and erase specific memories, it would be a 900-year-old Time Lord. But Burnett has another theory: that the Doctor didn't wipe Donna's memories, he simply disrupted her ability to recall them.

"Even if the Doctor could sever memories, it would be an immensely fiddly process," he says. "It would be easier and safer for him to put some kind of psychological block on those memories instead, to teach her brain that those memories are out of bounds. It's almost like giving someone a traumatic association. People with PTSD tend to show avoidant behaviours. If there's any possibility of encountering the cause of the trauma, they'll actively avoid it, sometimes without realising. The brain takes over and does it itself."

Burnett's theory is supported by events in the 2009 episode *The End of Time*, where the sight of everyone on Earth turning into supervillain The Master triggers dormant memories (it's a weird show).

"In the case of PTSD," says Burnett, "if you're exposed to triggers beyond your control, that could lead to those memories rushing back, because the brain's block may not be enough to suppress them." The Doctor's block will be tested again this November on BBC One, as Tennant and Tate reunite for a series of 60th-anniversary specials. Here's hoping it's a reunion to remember. **SF**

VERDICT

While resurrecting dormant memories is possible, total mind-wiping is a cliché most scientists would rather forget.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATION: JOE WALDRON

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